BORDER CROSSING: A CASE STUDY OF SELECTED SCIENTIFIC AND TRADITIONAL WORLDVIEW PRESUPPOSITIONS AMONG SWAZILAND HIGH SCHOOL STUDENTS

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KEY WORDS

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Collateral learning

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Concept mapping

Exemplary practice.

ABSTRACT

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PhD Thesis, School of Science and Mathematics Education, University of the Western Cape.

This study investigated: 1) the nature of worldviews presuppositions held by three groups of learners in Form IV classes in three high schools in Swaziland; 2) the nature of "cognitive border crossing" exhibited by the learners from the traditional to the scientific worldview and 3) whether or not three learning theories/hypotheses: border crossing, collaterality and contiguity were applicable to their conceptions of force, energy, work and power.

The study, situated within the socio-cultural constructivist theory, involved the administration of two instruments namely, "My Idea about nature" (MIAN) and the Physics Achievement Test (PAT), as well as the use of a Videotaped Group Discussion. Further the study adopted a quasi-experimental design modified after Solomon-3 control group design, in which three comparable groups – one experimental and two control groups, were investigated. The experimental and second control groups were exposed to exemplary teaching/learning strategies while the true control group was not so exposed. At the end of the instructional intervention, the discussions of two groups, each consisting of ten subjects from the experimental and second control groups, were video recorded to test whether or not their views had changed from alternative to scientifically valid conceptions of selected concepts.

The findings of the study showed that the subjects, regardless of their gender, age and interest in science, exhibited: (1) varying degrees of traditional as well as scientific notions about selected phenomena; (2) a multiplicity of worldview presuppositions and 3) different forms of cognitive border crossing thus corroborating the three learning theories/hypotheses. However, the study revealed that each of the three theoretical models did not seem to fully capture the phenomenon of border crossing, and hence the positing of the "African Learner Model", which combined the three models to show how, when, and in what contexts the various types of border crossings took place in the mind of a learner. The implications of the findings for teacher training, curriculum development and instructional practices were highlighted for a closer consideration.

October 2002

DECLARATION

I declare that Border Crossing: A Case Study Of Selected Scientific And Traditional Worldview Presuppositions Among Swaziland High School Students is my own work, that it has not been submitted before for any degree or examination in any other University, and that all sources I have used or quoted have been indicated and acknowledged by complete reference.

CYNTHIA GCINAPHI FAKUDZE OCTOBER 2002

Signed: ...CFakudze...

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TO GOD BE THE GLORY BOTH NOW AND FOREVER MORE!

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LIST OF SISWATI AND LOCAL WORDS USED IN THE TEXT

Ingwenyama: a title bestowed on a Swazi king that means lion

Indlovukati: the title of the queen mother, which means elephant

Incwala: a harvest celebration and a first fruits ceremony

Umhlanga: a national ceremony in the form of service to the queen mother performed by unmarried maidens.

Lusekwano: a species of acacia that grows sparsely in a few areas in Swaziland and near the coast

Inhlambelo: a sacred hut within the king's kraal

Emabutfo: Swazi regiments

Tokoloshe: a legendary dwarf who dwells near rivers amongst boulders and in the reeds, and who is only seen by children who have not reached the stage of puberty

Lihabiya: comes as a result of a spell cast by a man who has been rejected by a girl to whom he has been making advances

Tinyanga: traditional healers

Umtsakatsi: witch, wizard, sorcerer

Emadloti: Ancestral spirits

Likhombo: Bad luck

Inhlawulo: a fine paid to the chief

Indvuna: a chief's representative

Tipoko: ghosts

Ihhomulayini: electric saw

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

This study was carried out in the Kingdom of Swaziland, which is one of the smallest political entities of continental Africa (Regional Surveys of the World, 1997). Swaziland is a land-locked country in Southern Africa that shares borders with South Africa (north, west, south and southeast) and Mozambique (east). It has four districts, namely: Hhohho, Manzini, Lubombo and Shiselweni. The study was conducted in the Shiselweni district, which is considered to be more rural than the other districts. Swaziland was founded by Bantu people called Swazis that migrated into the country from Mozambique in the last half of the 18th century (The Statesman's Yearbook 2002). According to Marshall (1999), Swaziland became a British protectorate when colonial rule was established in 1903 and was led to independence by King Sobhuza II in 1968. It is now a dual monarchy with a king (the Ingwenyama, currently King Mswati III since April 25, 1986) and a Queen Mother (the Indlovukati). The kingdom has a population of slightly more than one million out of which 97% are African and 3% European. 66.1% of the population is rural. According to the Europa World Year Book (2001), about 60% of the population profess Christianity of which 55% are protestant and 5% Catholic. Ten percent of the population is Muslim while 30% belong to indigenous beliefs (Marshall, 1999).

The Swazis are known for their high esteem of culture and traditions. They strongly believe in the preservation of their cultural beliefs and traditional customs. These traditional beliefs are emphasized and promoted in school as well as in each household, the local media, parliament and chiefdoms, and are seen as a way of preserving the identity of the Swazi people. According to Kuper (1986), it was King Sobhuza II, the present king's father, who guided Swaziland into the modern post-colonial era while at the same time trying to maintain its unique cultural identity. Sobhuza II had argued that the changes required to make traditional institutions responsive to modern needs had to be based on the Swazi cultural heritage as a model. He placed great emphasis on the potential contribution of the educational institution to the fostering of cultural nationalism. He argued that education should not be secularised but that it should also not be confused with Christianity. According to Sobhuza II, if education developed apart from religion, it would undermine the unity of the sacred kingdom. As a result of the recommendations of the first constitutional commission, and particularly after independence, the education department became more Swazi-oriented and extended the Swazi section of the curriculum. There was also "an attempt to get interesting siSwati textbooks, and a genuine effort was made to inculcate into the students a pride in Swazi history and a knowledge of Swazi customs" (Kuper, 1986: 144).

Two public holidays are included on the country's calendar, which are dedicated specifically to the observation of two traditional ceremonies that are religious in nature. The first ceremony is called the Umhlanga Reed Dance, which is attended by thousands of young maidens of school-going age. These girls converge each year at the Ludzidzini Royal Residence to start an approximately twenty five-kilometre walk to fetch long flexible reeds from a riverbank, which are required for the fences surrounding the royal quarters. According to Kuper (1986), the ceremony has different levels of meaning. In practical terms, the girls are performing a national

service to the queen mother, and at a 'more symbolic level, the reeds, costumes, and the dance songs convey their own message in terms of Swazi concepts of fertility, chastity, and the power of womanhood' (p.147). The ceremony culminates with a reed dance by the girls in front of the king, queen mother, members of the diplomatic corps, and the whole nation on a day that is declared a public holiday.

The second traditional ceremony is called the Incwala or First Fruit ceremony in which thousands of Swazi males congregate yearly at the Royal residence. According to Marwick (1966), the Incwala is regarded as the chief ceremony for the Swazis. As an agricultural ritual the Incwala marks the time from which the new crop may be eaten. From a military point of view, the ceremony appears to be a review of the emabutfo (regiments). Lemarchand (1977) has observed that

> The Incwala is many things. It is a harvest celebration and a first fruits ceremony. It is at one and the same time a metaphysical drama in which the line between the sacred and the profane is demarcated and a morality play. But most importantly, it is an act of political solidarity designed to perpetuate the glory of the Ngwenyama and reaffirm the unity of the people (p.134)

During the first few days of the Incwala, thousands of boys of school-going age walk about twenty kilometres to fetch a sacred shrub (lusekwano), which grows in the lowveld. According to Kuper (1980), the lusekwano is a species of acacia that grows sparsely in a few areas in Swaziland and near the coast. This shrub grows with amazing rapidity, remaining green for many months, even when plucked. Its characteristics are symbolic of the ingredients that make up the Incwala, namely: quick growth, greenness, and ever-recurring fertility. The Swazis believe that the shrub was made expressly to distinguish between the 'pure' from the 'impure'. This is a distinction drawn between men with children and "youth who, though they have had love affairs, have not made any woman pregnant. If anyone 'impure' were to pick the Lusekwano, its leaves would shrivel" (Kuper, 1980:209). The lusekwano is used to build the inhlambelo kraal in which the king performs part of the Incwala ceremony (Marwick, 1966). These ceremonies also end up with a traditional dance in which the king and the male regiments (emabutfo) dance before the whole nation on the declared public holiday. During the Incwala dance, 'Incwala songs are sung that are absolutely taboo at any other time of the year and a heavy fine is imposed on anyone who dares to sing them at other times' (Marwick, 1966: 190). All the ceremonies described above probably may have, among other things, influenced the inclusion of cultural extramural activities in the school curriculum, which are given the same status as physical education. Each school is encouraged to take part in cultural competitions, which include cultural activities as traditional dances.

Statistics over the years have shown that there are very few Swazi learners who enroll in secondary schools and tertiary institutions. According to the Europa World Year Book (2001), in 1996 only 52% of children of the appropriate age group were involved in secondary schooling. The Regional Surveys of the World (1997) reports that there were 52 571 children in 165 secondary schools, 1 730 at university, 924 in teacher training, and 2 034 in technical and vocational institutions. These statistics may have changed over the years but the statement that very few of these learners end up majoring in science has probably remained the same. Many reasons have been given for this state of affairs. Among others, the often mentioned reasons include: i) the shortage of qualified science teachers in schools, ii) shortage of resource materials and laboratory equipment in schools and iii) the use of the Cambridge Ordinary (O')

Level Syllabus which is viewed by many as foreign and specifically designed for Western learners.

Urevbu (1984) and Ogunniyi (1986) have argued that most of the science curricula in Africa, of which Swaziland is a part, are modelled on those in the West and hence do not reflect the cultural background of the learner. Studies in non-western societies have also revealed that learners hold alternative worldviews to that of science due to their cultural backgrounds, and that such alternative worldviews might in fact prevent the learner from developing a valid scientific worldview. Ogunniyi, Jegede, Ogawa, Yandila and Oladele (1995) argue that:

> Learners' disposition to the study of science is conditioned to a great degree by the worldview prevalent in their socio-cultural environment...(and that) the socio-cultural environment determines to a great extent how an individual functions, interprets and reacts to various stimuli...With respect to science education, a knowledge of what teachers and students bring into the classroom is critical in situating the teaching-learning processes within a meaningful context (Ogunniyi et al 1995, p 818)

Some researchers are of the view that the gap between the scientific worldview and the learners' cultural/ commonsensical worldviews might be caused largely by poor instructional practices and what their teachers believe to be true about natural phenomena, whether or not such view are scientifically valid (Aikenhead, 1996; Ogunniyi et.al. 1995). The subject of the learners' culture and worldviews has received a lot of attention among science educators worldwide (e.g. Ogunniyi, 1987, 1988, 1995, 1997, 1998; Ogunniyi et al, 1995; Aikenhead, 1996, 1997, 1999; Jegede and Okebukola, 1989, 1991b; Cobern, 1994, 1996b; George, 1999a, 1999b; Aikenhead and Jegede, 1999; Adam, 1999; Baker and Taylor, 1995; Jegede 1995, 1997b; Okebukola and Jegede, 1990). It was against this background that this study attempted to determine the nature of Swazi science learners' worldview presuppositions with respect to selected natural phenomena. The underlying assumption is that the subjects of this study hold certain indigenous worldviews, which might be inimical to the study of science. The validity or otherwise of this assumption of course will depend on the findings of this study.

1.2 THEORETICAL FRAMEWORK

This study is situated within a worldview theory as espoused by socio-cultural constructivists (e.g. Aikenhead, 1996; Jegede, 1995 and Ogunniyi, 1995), which is an explanatory model borrowed from cultural anthropology to explain mental representations of reality (Ogunniyi, 1995). The concept of worldview has been defined in a variety of ways. According to Proper as cited by Ogunniyi (1995), a worldview is " a set of beliefs held consciously or unconsciously about the nature of reality and how one comes to know it." It is, according to Kearney in Cobern (1996b),

> A culturally organized macro thought: those dynamically interrelated basic assumptions (i.e., presuppositions) of a people that determine much of their behaviour and decision making as well as organizing much of their symbolic creation . . . and ethno philosophy (p.584)

Cobern (1996b) explicates the concept of worldview to science education. Using Kearney's logico-structuralism derived from cultural anthropology, he contends that a worldview provides a non-rational foundation for thought, emotion, and behaviour. It also provides a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world. He has defined worldview as fundamental beliefs, i.e., presuppositions about the world that support both common sense and scientific ideas. According to him, these suppositions then become the learners' worldviews, which they then use to support the ideas that they bring to class.

The study is underpinned by the socio-cultural constructivist view that a learner does not enter into the science classroom with a blank mind, but holds certain pre-conceptions and/or alternative worldviews, which he/she has acquired from his/her socio-cultural environment. Since no one lives in a socio-cultural vacuum, the socio-cultural environment, according to Ogunniyi (1995), determines to a large extent, the way in which an individual functions, interprets and reacts to diverse natural phenomena. He further states that not all that is in the learner's mind has been personally experienced. A great portion of the knowledge that the learner uses to direct his/her life has been acquired formally, informally or vicariously. Ogunniyi (1995) further points out that, at whatever level learning takes place (including personal experience), the individual learner is actively searching for meaning that would facilitate his/her corresponding behavioural change.

A group of science educators have proposed theories/hypotheses which emanate from the worldview theory to explain how learners move between their everyday life worlds and the world of science, and how they deal with cognitive conflicts between these two worlds. Some of the theories/hypotheses are: Border Crossing, the Collateral Learning theory and the Contiguity-Learning Hypothesis (Aikenhead, 1996; Ogunniyi, 1995, 1996, 2000, 2002a and b; Jegede, 1995, 1997b; Aikenhead and Jegede, 1999).

According to Aikenhead (1996), the Border Crossing theory states that in order to acquire the culture of science, a learner should intellectually shift from his/her everyday life-world with its traditional world-view presuppositions to that of school science, which might obviously result in conflicts. Aikenhead (1996) used four types of border crossing between the learner's traditional worldview and that of school science, namely: smooth, managed, hazardous, and impossible.

Smooth border crossing occurs when the students' worldviews are congruent with school science. Managed border crossing occurs when the learner's worldview is different from the science worldview thus requiring the transition from one to the other to be managed. Hazardous border crossing occurs when the learner's worldview and scientific worldview are rather diffused leading to hazardous transitions from one worldview to the other. Impossible border crossing occurs when the learner's worldview and that of science are highly discordant causing students to resist transitions from one worldview to the other.

Jegede (1995) proposed the Collateral learning Theory as a mechanism to explain how a learner harmonizes the conflict resulting from the contact between traditional worldview and that of science. He asserts that a non-western learner in a science classroom will construct scientific concepts side by side, and with minimal interference and interaction, with their indigenous concepts (related to the same physical event). Jegede (1995, 1996, and 1997b) states that there are variations in the degree to which the conflicting ideas interact with each other and the degree to which conflicts are resolved. He has identified four types of collateral learning, namely: parallel, secured, dependent and simultaneous collateral learning. In the parallel collateral learning type, the conflicting schemata do not interact at all. In secured collateral learning, the conflicting schemata consciously interact and the conflict is resolved in some manner. In dependent collateral learning, the schema from one worldview or domain of knowledge challenges another from a different worldview or domain of knowledge, to an extent that permits the student to modify an existing schema without radically restructuring the existing worldview or domain of knowledge. Simultaneous collateral occurs when learning a concept in one domain of knowledge or culture can facilitate the learning of a similar or related concept in another milieu. These types are not separate categories, but points along a spectrum depicting degrees of interaction and resolution.

Ogunniyi's (2002b) posited the Contiguity Learning Hypothesis as an explanatory model for cognitive border crossing. His Contiguity Learning Hypothesis:

> Construes border crossing as a dynamic, non-linear intellectual process triggered by contiguously interacting worldviews schemata resulting in a massive convergence of neural network and hormonal activities directed at cognitive restructuring and adaptability... Border crossing is a learning process evinced by the interacting worldview schemata in a given context. The context itself is the product of dynamic physico-chemical reactions as well as psycho-metaphysical schemata or embodied experience regulating the whole process. The physiological aspect of this interaction is explainable in terms of neural and hormonal activities while the psycho-metaphysical aspects relate to the interest shown. (p.8-9)

A more detailed discussion of these constructs will follow in chapter two.

1.3 STATEMENT OF THE PROBLEM

As mentioned earlier, the underlying assumption of studies conducted on learners' views about natural phenomena is that the learners' understanding of natural phenomena is conditioned by their worldviews whether or not such views accord with valid scientific viewpoints. These worldviews are responsible for the learners'

disposition to the study of science, especially in the case of non-western learners. Since the socio-cultural environment determines, to a great degree, how an individual functions, interprets and reacts to stimuli, a number of science educators have, therefore, proposed a science curriculum which relates more closely to the learner's societal or cultural environment so as to minimize as much as possible the conflict that might arise from his/her view of the world and that of science (Ogawa, 1986; Cobern, 1994, 1996b; Ogunniyi et al., 1995; Jegede, 1997b; Aikenhead and Jegede, 1999; George, 1999a, 1999b).

As mentioned above, Urevbu (1984) and Ogunniyi (1986) have pointed out that most of the science curricula in African countries are modelled on those in the West and hence do not reflect the cultural background of the learner. According to Ogunniyi (1986), the content of school science does not make a clear distinction between traditional ways of viewing the world and that of science. This has resulted in making learners from these developing countries feel that school science is like a foreign culture to them (Maddock as cited in Jegede and Aikenhead, 1999). Such feelings, according to Jegede and Aikenhead (1999), stem from fundamental differences between the culture of western science and that of the learners' indigenous cultures. The differences, according to Ogunniyi (1995), are due to the fact that

> An African (learner) does not have an attitude of externality to the world. He/she does not see him/herself to be separate from the physical world in which he/she finds him/herself, but as part thereof. Unlike the scientist whose physical world is impersonal and irrational, the world of an African (learner) is rational and metaphysical. The true metaphysics is necessarily deductive and all aspects of life are made to flow from metaphysics (p. 619)

It was against this background that the present study was carried out. The study attempted to investigate: (1) the type of worldview presuppositions held by Swazi learners towards a few selected natural phenomena; and (2) whether or not the theories/hypotheses of collateral learning, contiguity learning and cultural border crossing are applicable to the subjects' traditional and/or scientific views with respect to the concepts of force, energy, work and power.

1.4 RATIONALE FOR THE STUDY

It was necessary for this study to focus on the learners' conceptions of forces, energy, work and power because research has shown that learners from many different countries, including Swaziland, exhibit alternative conceptions in these and other Physics topics such as electricity, heat and light, and so forth (see Driver and Erickson, 1983; Thijs, 1992; Thijs and Van Den Berg, 1995; Baker and Taylor, 1995; Govander, 1999). Further more, the topics of force, energy, work and power were chosen for the study because these scientific concepts could be used to explain a number of natural phenomena and practices found in typical rural Swazi socio-cultural environment (e.g., lifting a bucket of water onto one's head). In other words, they seemed to have the potential to yield the envisaged results from the investigation on the effects of the cultural factors on the learning of science discussed below.

The study had to also take into account effect of cultural factors on the learning of science because of the notion that the cultural background of each learner has a significant effect on their ways of knowing and learning science, that is, it affects their ability to fully comprehend and manipulate scientific concepts. Also, research has shown that attempts to nationalize Western science curricular in non-Western countries have proven ineffective because of the problem of 'poor' fit between language, culture and beliefs of many non-western learners, and the cultural meanings embedded in the (western) language of science education (Baker and Taylor, 1995). According to Thijs and Van Den Berg (1995), these cultural factors, relative to alternative conceptions, include: language, environment, social structure characteristics, traditional values and beliefs, modes of thought and epistemology. However, this study opted to concentrate on traditional values and beliefs, the modes of thought as well as epistemology for the reasons given below.

It was shown at the beginning of this chapter that education in Swaziland was deliberately structured to encompass Swazi cultural factors during the period when the country was undergoing the transition from colonial rule to independence (Kuper, 1980) even though these expectations have not been realized in the science classrooms. As a result of this structure, a Swazi learner might oftentimes find him/herself having to cognitively balance between the Swazi traditional beliefs learnt from his/her socio-cultural environment and the scientific views found in school science. For example, he/she might be required to make a cognitive balance between his/her traditional knowledge of the concept of Lusekwano (the sacred shrub discussed earlier) and the scientific concepts found in biology classes. The Swazi concept is that the Lusekwano shrivels when picked by an 'impure' male while the scientific concept, on the other hand, might give other reasons contrary to that such as plasmolysis due to lack of water and so forth.

Thijs (1992) has argued that a culture should have certain traits such as appropriate reasoning patterns (an aspect of 'modes of thought' and a factor of epistemology) if the scientific enterprise is to flourish. According to Thijs and Van Den Berg (1995), these reasoning patterns involve the process of reaching conclusions by using arguments. They are of the opinion that the reasoning patterns of western and non-western learners are likely to differ, and that the differences in reasoning play a role in the remediation of alternative conceptions, implying the important bearing that culture has on modes of science teaching and learning. The reasoning patterns of the Swazis concerning the phenomena occurring in their socio-cultural environment can be traced in what calls Kuper (1980) their 'ritual knowledge.' She has observed that for the Swazis, what they call ritual knowledge or 'heavy knowledge', is:

> A powerful tool to use in most private and communal undertakings… It is used to bring life the fullness that it promises and so rarely yields. It bridges the gap between the probable and the improbable (between our concept of reality and unreality). Swazi reality is full of wonder.... Unreality scarcely exists, and since actual disproof of ritual efficacy is lacking, doubt is the limit of Swazi disbelief. There is no rigid dichotomy of nature into the natural and supernatural; supernatural powers are all pervasion. This does not mean that the Swazis lack pragmatic knowledge; indeed such is obviously essential for the continuance of all human societies. But everything to them has two aspects, the ordinary and the potentially extraordinary, and the two overlap and interact (Kuper, 1980: 161).

Based on the abovementioned observation, it seems evident that the probability of a Swazi learner possessing reasoning patterns that are contrary to that of science is very high, hence the need for a study that considers their effect on his/her conceptions of force, energy, work and power as well as one that suggests an instructional approach that encompasses the learners' cultural beliefs.

The reasons why the Swazi learner does not pursue science have not been documented although there are both structural and educational possibilities. One explanation could be that the transition from traditional worldviews to the scientific worldviews might be too great, without any sort of bridging mechanism. Curriculum development is another possible reason for the small number of Swazi people in the sciences. According to Sutherland and Dennick (2002), the science curriculum is assimilative in its own right because it gives the impression that the Western view of nature is the only legitimate way of learning about the natural phenomena, thereby reducing traditional knowledge to being inferior and non-scientific. Nevertheless, as mentioned earlier, research findings (e.g. Proper, Wideen and Ivany, 1988; Jegede and Okebukola, 1991a, 1991b; Cobern, 1993) have suggested that the gap between the worldview of the learner and the worldview inherent in science education could be bridged by using instructional strategies that identify and discuss the prior cultural learning of the learner, and that enable him/her to test those beliefs in the context of a scientific model. For instance, Baker and Taylor, (1995) have argued that these instructional strategies consisting of old view analysis followed by new view learning, combined with a process of harmonization in which science is related to the indigenous culture, might contain the answer to more effective science education in non-western countries. It was, therefore, found to be appropriate for this study to verify the plausibility of such a claim in a Swazi context.

As indicated earlier, the study chose socio-cultural constructivism as the most appropriate theoretical framework because of the theories/hypotheses that have emanated from this paradigm that suggest how learners in non-western societies 'fill the gap' between their traditional worldviews and that of science. These theories/hypotheses seemed to better capture the process of transcending the gap from one worldview to the other. They have also depicted the importance of the learner's socio-cultural environment as well as the effect of his/her cultural background on his/her learning of school science. Three of these theories/hypotheses, namely, the Border Crossing Theory (Aikenhead, 1996), the Collateral Learning Theory (Jegede, 1995) and the Contiguity Learning Hypothesis (Ogunniyi, 1995), prompted the researcher to explore their applicability to the Swazi learners' conceptions of force, energy, work and power.

1.5 PURPOSE OF THE STUDY

In the light of the foregoing discussion, the aim of the study was to determine the nature of border crossing among Swazi secondary school learners with respect to selected natural phenomena. The natural phenomena referred to in this study are those usually associated with certain cultural practices which include lightning, thunderstorms, hail storms, and drought which are sometimes viewed as ancestral punishment for not observing certain traditional rites, e.g. believing that hailstorms that destroy fields are a sign that the ancestors have been provoked by people who work in the fields while a funeral is taking place in the same vicinity.

More specifically the study aimed at: (1) identifying the learners' conceptions (i.e. indigenous and scientific knowledge) of selected natural phenomena using basic science concepts of forces, energy, work and power; (2) exploring the learners' explanations of selected experiences with natural phenomenon; (3) analysing the nature of the learners' explanations regarding selected traditional practices found in their socio-cultural environment; and (4) determining the applicability or otherwise of extant cognitive theories/hypotheses to the learners' traditional and scientific worldviews with respect to selected natural phenomena.

1.6 RESEARCH QUESTIONS

In pursuance of the problem of the study answers were sought to the following questions:

- What is the nature of the worldview presuppositions held by Swazi secondary school learners on selected natural phenomena?
- Is there a significant difference between the scientific and traditional views about forces, energy, work and power held by the learners exposed to an instructional model and those not so exposed?
- Do the learners' sex, age group, interest in science influence their traditional and scientific views about force, energy, work and power?
- How applicable are three cognitive theories/hypotheses (i.e. border crossing, collaterality and contiguity) to the learners' conceptions of force, energy, work and power?

1.7 RESEARCH HYPOTHESES

In seeking answers to the above questions the following null hypotheses were tested:

- HO_1: Swazi secondary school learners do not hold discernible worldview presuppositions about selected natural phenomena.
- HO_2: There is no significant difference between the scientific and traditional views about force, energy, work and power held by the learners exposed to an instructional model and those not so exposed
- HO_3: The learners' conceptions of force, energy, work and power are not significantly influenced by their sex, age group, and interest in science.
- HO_4: The three cognitive theories/hypotheses (i.e. border crossing, collaterality and contiguity) are not applicable to the learners' conceptions of force, energy, work and power.

1.8 SIGNIFICANCE OF THE STUDY

The researcher is not aware of any study in Swaziland specifically concerned with investigating learners' worldviews as well as their border crossing from a traditional worldview into that of science. It is hoped that the study would prove informative and useful to attempts directed at:

- Helping to situate science education, especially in non-western environments, within a relevant theoretical framework
- Clarifying issues relating to possible conflicts frequently mentioned in the literature between school science and traditional/commonsensical notions about diverse natural phenomena (see Ogunniyi 1988, 1995; Ogunniyi et al 1995; Jegede 1995,1997b; Jegede and Okebukola 1989, 1991a, 1991b; George 1999a, 1999b; Aikenhead, 1999; Aikenhead and Jegede, 1999; Thijs and Van Den Berg, 1995)
- Providing additional information about the phenomenon of border crossing between a learner's life-world and that of school science (see Aikenhead 1996, 1999; Aikenhead and Jegede, 1999; Manzini, 2000).
- Contributing towards the science curriculum in non-western societies. Cultural clashes between learners' life-worlds and the world of school science challenges science educators to develop culturally sensitive curricula and teaching methods that could reduce the issue of foreignness experienced by learners in science classes (e.g. Aikenhead 1996,1999; Aikenhead and Jegede, 1999; Jegede 1995; Jegede and Okebukola, 1991a, 1991b; Ogunniyi 1995,1987, 1988, 1996; Ogunniyi et al 1995)

- Making some contribution towards efforts directed at learners' conceptions of school science. This is particularly important for teachers whose learners come from multi-cultural environments.
- Providing some data on the worldview of non-western learners. The paucity of data on learners' alternative worldviews warrants a more scholarly attention.
- Suggesting a model explaining how and under what conditions non-western learners, African in particular, cross borders between their traditional worldviews and that of science.

1.9 DELIMITATION OF THE STUDY

The present study was limited to an investigation of the nature of worldviews and border crossings of three groups of Grade 11 learners on the topic of force, energy, work and power from the Shiselweni district of Swaziland. Time was spent in each group during which they were given questionnaires, and pre/post tests. The researcher taught two of the groups for a period of six weeks. Some of these subjects were video taped while discussing some cultural issues based on two of the questions on the Physics Achievement Test. Details of the findings through the questionnaires and tests are discussed in chapter 4.

1.10 DEFINITION OF TERMS

Worldview:

This is a set of beliefs held consciously or unconsciously about the nature of reality and how one comes to know it (Ogunniyi, 1995).

Life worldview:

This is the totality of human experiences with both inanimate and animate objects in one's immediate environment, which are highly instrumental to one's behaviour, feelings and decision-making about natural phenomena in the universe (Ogunniyi, 1988)

Traditional worldview:

This is a system of thought, which is anthropomorphic in nature (Ogunniyi, 1988; Jegede, 1997b)

Scientific worldview:

This is a system of thought that is mechanistic in nature (Ogunniyi, 1988; Jegede, 1997b)

Culture:

This consists of norms, beliefs, values, expectations and conventional actions of a group (Phelan, Davidson and Cue in Aikenhead, 1996)

Crossing:

The cognitive shift from one worldview to another

Cultural border crossing:

This is the process of helping students to cross over from their cultural worlds into the worlds of school science with its cultural trappings (Aikenhead, 1996)

Collateral learning:

This is the process whereby a learner in a non-western classroom constructs, side by side and with minimal interference and interaction, western and traditional meanings of a simple concept (Jegede, 1995).

Contiguity learning:

This is a bridge principle depicting how two or more co-existing or successive mental states dynamically tend to interact, recall, collaborate, compete, supplant or dominate one another depending on the threshold of each and the world view template serving as a frame of reference in a given context (Ogunniyi, 1995).

Concept Map:

An active learning tool with numerous uses in the science classroom (Kinchin, 2001)

1.11 AN OVERVIEW OF THE STUDY

Chapter 2 focuses on the literature review. It can be broadly described as comprising of two parts. The first part is an expansion of the theoretical framework that was briefly described in this chapter. It has five sections: the first describes the main Worldview Theory; the second to the relationship between the worldview theory and learning, and the other three sections are dedicated to the subsequent theories emanating from the worldview theory (Border Crossing, Collateral Learning, and Contiguity Learning). The second part is about studies that were carried out on the different aspects of the Worldview Theory as related to science education. Chapter 3 reports on the selection of experimental design, research procedures as well as a description of the instruments used. The characteristics of the subjects, and the instructional strategies used for the intervention/treatment are also described.

Chapter 4 reports the results obtained after the implementation of the research procedures described in Chapter 3. The results are grouped under headings derived from the four research questions given in section 1.5. The first section is on the nature of the subjects' worldviews. The second section is on the effect of the intervention/treatment. Section Three is about the influence of sex, age and interest in science on the subjects' conceptions of force, energy, work and power. The last section is an investigation of the applicability of three theories/hypotheses to the subjects' presuppositions about some natural phenomena found in their socio-cultural environment.

Chapter 5 is in two parts. The first sections consist of a discussion on some issues that were noted during the data analysis in chapter 4. This is followed by a discussion of the African Model, which is a combination of the three theories/hypotheses that have attempted to describe how an African Learner accesses the scientific worldview found in school. Chapter 6 deals with general conclusions, implications and recommendations for future research. Consideration is also given to the efficacy of the study in achieving its aims as well as answering the research questions in Chapter 1. The last two sections deal with the bibliography and appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This study examines a number of worldview presuppositions held by Swazi high school students about selected concepts (force, energy, work and power). It further explores the way the students have tried to resolve the cognitive conflicts that might have occurred in their minds as they crossed the cultural borders between their traditional worldviews and that of school science. As already mentioned in chapter one, the reason for focusing on worldview has been brought about by the general awareness among science educators worldwide that learners' disposition to the study of science is conditioned to a great degree by the worldviews prevalent in their socio-cultural environment and their confidence in what teachers hold to be true about natural phenomena (Ogunniyi et al 1995). Current research has also suggested that science teachers and learners who are exposed to traditional (indigenous) wisdom and who have some level of commitment to it (as is the case among the Swazis) are likely to find that, to some extent, they are required to function in two worlds; the traditional world and that of science. The differences in the worlds would require them so to speak to 'cross cultural boundaries' from one worldview to another. The subject of worldview and culture dealt with in this study are closely woven together (Allen and Crawley, 1998). In effect, a worldview may be described as the variant of the concept of culture (Kearney as cited in Allen and Crawley, 1998).

This chapter starts by discussing the Worldview Theory, which serves as the basis for the socio-cultural constructivist views that under-pin this study. The following sections will discuss the relationship between the worldview theory and related aspects such as science education, the socio-cultural environment, and the theories/hypotheses that have been specifically proposed to explain the phenomenon of cognitive border crossing as well as the resolution of conflicts that might arise in the process. The last section will discuss studies that have been conducted on the different aspects of the worldview theory.

2.2 THE WORLDVIEW THEORY

As has been mentioned earlier in chapter one, the concept worldview has been defined in a variety of ways. Allen and Crawley (1998) have defined it simply as the way people think about themselves, their environment, and the abstract ideas such as truth, beauty, causality, time and space. In other words, it is the way people have of looking at reality, the basic assumptions and images that provide a more or less coherent way of thinking about the world, the coherent structure into which a person's thinking is based, and the epistemological structure by which the plausibility of assertion is judged. Cobern (1993) has regarded worldview as a culturally dependent, generally subconscious, fundamental organization of the mind, which manifests itself as a set of presuppositions that predispose one to feel, think, act and react in a certain predictable manner. According to Ogunniyi (1998), a person's worldview has an organizing value for experience. It is not only a mechanism for organizing an individual organically into a socio-cultural milieu, but also a dynamic cultural framework that determines the likelihood in which a new idea is assimilated in the cognitive structure. For Aikenhead (1996), worldviews provide a special plausibility structure of ideas, activities, and values that allows one to gauge the plausibility of any assertion. Proper, Wideen and Ivany (1988) have construed a worldview to be " a set of beliefs held consciously or unconsciously about the basic nature of reality and how one comes to know about it." They have argued that all people possess worldviews, which are germane to what they think and do. Such views are acquired through a variety of influence including the family, media, and interpersonal relationships and through the ways our institutions are structured and the way they function.

According to Allen and Crawley (1998), it was Kearney who proposed a logico-structural theory of worldview. The two key points of this theory are: a) that worldviews strive towards maximum and logical and structural consistency; b) that worldviews are given coherence as shaped by the necessity of having to relate to an external environment. Allen and Crawley (1998) have observed that Kearney's worldview theory has allowed us to make the link between worldview, which is an abstraction, and behaviour, which is what we actually observe. This is because:

> Our link from these abstractions to behaviour is the theoretical bias that specific worldview result in certain patterns of actions and not others. Therefore knowledge of a people's worldview should explain aspects of their cultural behaviour (Kearney as cited in Allen and Crawley, 1998, p.113)

Cobern (1996b) has related the worldview concept to science education by drawing on Kearney's worldview theory. He has adopted Kearney's logico-structural model of worldview, which consists of seven categories. These are: (1) *Self* which is the individual; (2) *Other/non-self* consisting of the environment or other beings; (3) *relationship* which is the interaction with the *other*; (4) *classification* which is the ordering phenomena into different categories; (5) *causality* which means the cause-effect relationship that people invoke to explain phenomena; (6) *space* which is the relationship between the environmental space of a people and their images of it; and (7) *time* which could be past, present, and future, oscillating or linear.

George (1999b) has proposed that Kearney's logico-structural model would seem feasible as a general framework for making sense of everyday understanding since one's worldview is formed from the composite of the seven categories mentioned above, and also allows one to adapt to the environment. However, Ogunniyi (1996), even though he has acknowledged the usefulness and relevance of these universal categories, has pointed out:

- That the universals are by no means exhaustive. According to him, the universals do not include such tangible experiences as feelings, imagining, insight, will, beliefs, interests, intuition, chance, etc
- The weaknesses of induction. He has argued that we can never isolate all the universals constituting a worldview, since there are an infinite number and varieties applicable to a given context. We must assume that as soon as Kearney gets hold of certain critical universals, he switches (like the physician) to deductive logic to make sense of a situation.
- That the universals are not easy to define without running the risk of tautology.
- That the representation of "significant others" is not problem free. He has argued that human behaviour must be cautiously related to thought because the link between the two is rather tenuous. For example, a person acting on an irrational but internalised compulsion may be reacting from what the significant other (e.g. father or mother) has spoken from the past.
- And that the notion of significant "other" and the concept of "self" are far from being clear.

According to Allen and Crawley (1998), worldview as a theoretical model was developed by western social scientists as a tool for understanding non-western ways of thinking.

2.2.1 Traditional Worldview Versus Scientific Worldview

Jegede and Okebukola (1991b) have argued that since early times human beings have always interpreted nature from the two distinct viewpoints of anthropomorphism (traditional worldview) and mechanism (scientific worldview). A number of science education researchers have distinguished between the characteristics of the traditional worldview held by learners and those of science education. They claim that the traditional worldview:

- Is anthropomorphic, monistic, metaphysical and has vitality (Ogunniyi, 1988; Jegede, 1997b)
- Is based on people (Horton in Ogunniyi in 1988)
- Seeks mythological generalizations (Ogunniyi, 1988)
- Is rational, pragmatic, unequivocal, authoritative, experiential, non-testable and non-falsifiable (Ogunniyi, 1987; 1988; 1995)
- Is orally communicated (Jegede, 1997b; Ogunniyi, 1988)
- Considers the elder's exposition as truth not to be challenged (Jegede, 1997b; Ogunniyi, 1988)
- Views learning as a communal activity (Jegede, 1997b)
- Is a product of close predicament (Ogunniyi, 1988)

The scientific worldview, on the other hand:

- Is deterministic and metaphysical, mechanistic, exact and hypotheses driven (Ogunniyi, 1988; Jegede, 1997b)
- Is based on things (Horton in Ogunniyi, 1988)
- Seeks empirical laws, principles, generalizations and theories (Jegede, 1997b)
- Is testable, falsifiable, tentative, revisionary, anti-authoritarian and impersonal (Ogunniyi, 1988, 1995)
- Is primarily documented via print (Jegede, 1997b)
- Is tentative and challengeable by all (Jegede, 1997b)
- Views learning as an individual enterprise (Jegede, 1997b)
- Is a product of open predicament (Ogunniyi, 1988)

2.2.2 Traditional Worldview Categories

For the purpose of research and ease of reference, some science educators (e.g. Ogunniyi et al, 1995; Bandiera, Neves and Vicentine, 1999) have grouped related aspects of the traditional worldview into categories. This study has adopted these categories for analysing some of the data in chapter 4. The categories are as follows:

2.2.2.1 Magic and Mysticism

According to the American Heritage Dictionary, edited by Morris (1982), magic is an art that purports to control or forecast natural events, effects or forces by invoking the supernatural. Very often it involves the use of charms, spells, or ritual to attempt to produce supernatural effects in nature. However, for the purpose of this study, the operational definition formulated by Ogunniyi and Yandila (1994), which depicts magic as the force that is controlled from the world, and that produces supernatural effects, is adopted.

definition that describes a metaphysical phenomenon as one that appeals to the notion of state of being apart from the physical body.

A pseudo-science phenomenon, according to Ogunniyi and Yandila (1994), is one that is a seemingly scientific notion but containing erroneous conceptions. The Webster Comprehensive Dictionary (1995) defines the term "pseudo" to mean false, closely resembling and erratic; thus a pseudoscientific phenomenon is one that closely resembles a scientific one, but is erratic. For the purpose of this study the operational definition formulated by Ogunniyi and Yandila (1994) will be adopted.

2.2.2.3 Spiritism Category

According to the Webster Comprehensive Dictionary (1995), spiritism is an example of rare animism, which is a theory that inanimate objects possess spirits. It is also loosely regarded as a form of spiritualism, which is

> The belief that the spirits of the dead in various ways communicate with and manifest their presence to the living, usually through the agency of a person called a medium: a doctrine that there are beings not cognisable by the senses or characterized by the properties of matter, and that are therefore spiritual, as distinguished from material (The Webster Comprehensive Dictionary, 1995, p.1210).

However for the purpose of the study the operational definition formulated by Ogunniyi and Yandila (1994), which depicts spiritism as an appeal to another world of gods, spirits, devils, ancestors, etc is adopted.

2.3 THE WORLDVIEW THEORY AND SCIENCE EDUCATION

According to Novak (1988), significant advances occurred in two fields that have great importance for science education. These are: (1) learning psychology which moved away from behavioural psychology towards a science of cognitive functioning that places central emphasis on the role that concepts and conceptual frameworks play in human construction of meaning; and (2) epistemology which moved away from the empiricists' and positivists' views towards the constructivists' views which focus on the relationship between concepts, principles and theories we apply to observation of events or objects and the resultant construction of knowledge claims.

2.3.1 Constructivism

Driver and Erickson (1983) stated that there has been a growing interest in the notion that learners have intuitive ideas about natural phenomena. They claim that empirical work done in this area stems from a "constructivist epistemology" in which it is assumed that learners actively generate meaning from experience. Driver and Oldham (1986) claim that the constructivist view of learning has its roots in the interpretive tradition which has at its centre the importance of meaning as constructed by individuals in their attempt to make sense of the world. This tradition, they add, is also concerned with the intents, beliefs and emotions of individuals as well as their conceptualisations. The tradition also recognizes the influence that prior experience has on the way phenomena are perceived and interpreted.

Some science educators (Ogunniyi, 1995; Novak, 1988; Driver and Oldham, 1986) have claimed that constructivism has been greatly influenced by Ausubel's theory of meaningful learning. According to Ogunniyi (1995), the emphasis of the theory is to identify what a learner already knows before exposing him/her to a new learning material. In other words, meaningful learning involves relating new ideas with pre-existing ideas brought into the learning situation. Novak (1988) argued that Ausubel

was the first to make a comprehensive effort to present a theory of learning that dealt with the role of meaning and that it was he who spelled out in considerable detail the nature and role of concepts and propositional learning and the relevance of prior knowledge in meaningful learning. Driver and Oldham (1986) stated that Ausubel's has theory suggested:

> That if a new piece of information or concept can be integrated or subsumed into an existing structure it is more likely to be accepted. Hence, Ausubel argued the case for the provision of suitable advance organizers onto which new ideas can be fitted. If, on the other hand, few links can be made to prior knowledge and if the quality of these links is not high, there will be less chance of the idea being transferred to long term memory, and hence being retained and becoming useful (Driver and Oldham, 1986 p.107).

According to Novak (1988), Ausubel also clarified the distinction between rote learning and meaningful learning. To him the former is arbitrary, verbatim and non-substantive whereas the latter is the opposite.

It is against this background that Driver and Easley, as cited in Osborne (1996), initiated a reaction to the schools of thought on epistemology and a development stage model of cognitive growth. They argued that the achievement of learners in science depends more on specific abilities and prior experience than on general levels of cognitive functioning. Osborne (1996) argues that constructivism in science education has had its roots in this reaction and that

> …from here, research based on this premise developed rapidly, as did attempts to evolve a theoretical base for the empirical findings, to the point where the growth of the publications in this field has become almost exponential (p.53).

According Wheatley (1991), constructivism rests on two main principles: (1) that knowledge is not passively received, but is built up by the cognising subject and (2) that the function of cognition is adapted and serves the organization of the experiential world, not the discovery of ontological reality. He argues that from a constructivist perspective, knowledge originates in the learners' activities performed on objects and that these objects do not lie around ready made in the world but are instead mental constructs. According to him, constructivists view learning as the adaptations learners make in their functioning schemes to neutralize cognitive imbalances that arise through interactions with the world around them.

Cobern (1996a) has asserted that science education research and curriculum development efforts can benefit by adopting a constructivist view of science and science learning. According to him constructivism offers a different view of science and science learning. It assumes that logical thinking is an inherently human quality regardless of culture, and instead focuses attention on the process of interpretation that leads to understanding. It is a model of how learning takes place, rather than a theory of how rationality develops. Its focus is the content of thought rather than the formal operations of logic that thought can involve. For Cobern (1996a), constructivism is an apt metaphor that sees learning as the active process of constructing or putting together, a conceptual framework by the process of interpretation. He further argues that in constructivist thought, it is fundamental that learning involves negotiation and interpretation influenced by prior knowledge. As a model of learning, it implies that a student is always an active agent in the process of meaningful learning. Thus a student learns not by receiving a transmission, but by interpreting a message. One's interpretations are always influenced by prior knowledge, and a threshold of shared prior knowledge is essential in com
Constructivism leads one to expect that learners in different culture:

different perspectives on science.

Despite the many good points about constructivism, some science educators have raised issues that reveal its weakness. For example, Phillips (1995) has argued that constructivism has become something analogous to a "secular religion" and that it is "a powerful folktale about the origins of human knowledge". He alleges that constructivism has both 'good' and 'bad' points. The "good" points are:

- The emphasis placed on the necessity for active participation by the learner, together with the recognition of the social nature of learning;
- That most types of constructivism are modern forms of progressivism
- That constructivists have brought epistemological issues to the fore in the discussion of learning and the curriculum

The "bad point" is the trend with many forms of constructivist epistemology towards relativism, or towards treating the justification of human knowledge as being entirely a matter of socio-political processes or consensus, or toward the discarding of any substantial rational justification. He view is that

> Any defensible epistemology must recognise - and not just pay lip service to – the fact that nature exerts considerable constraint over our knowledge - constructing activities, and allow us to detect (and eject) our errors about it (Phillips, 1995: 12)

Jenkins (2000) has argued that, although the proponents of constructivism have advocated the idea that the development of understanding requires the active involvement or participation of the learner, this is by no means as straightforward as it sounds. He asserts that the notion that the mind actively constructing knowledge does not lead in any logical way to a rejection of the world as an external reality; nor does it require the problematic idea that science education is about "making sense" of the world rather than about establishing a valid scientific understanding of natural phenomena. He argued that the progressivist claims such as "children are natural scientists" and "everyone engages in scientific activity during the course of their everyday activities" are not only beguiling but, from the point of view of science education, misleading. He also pointed out that it has not been clearly spelt out what a science teacher is supposed to do if, as demanded by constructivism, he/she must take learners' "existing ideas" into account in planning science teaching activities. According to Jenkins (2000), constructivism has offered little in the way of guidance about how to best correct learners' alternative conceptions about natural phenomena, despite the fact that a range of so-called constructivist curriculum materials has been produced. He also argued that interactions with symbolic realities requires an acknowledgement of the importance of expert scientific knowledge on the part of the teacher, and that it shifts the debate away from learning as individual construction towards learning as a social activity, that is, towards so-called social constructivism. Jenkins (2000) also raised questions regarding the classroom activities and practices promoted by those who advocate constructivist pedagogy to introduce learners to scientific concepts and ideas. He asks: (1) if engaging students in the necessary practical activities is the most efficient way of promoting their learning; (2) what it is that "constructivist teachers" wish their students to "construct" during the course of their science lessons; and (3) if classroom activities and practices can be justified in terms of the time and resources associated with them.

Ogunniyi (1995) has asserted that, as a result of studies in the field of sociology of learning, research in science education has shifted from personal constructions to contextual constructivism with greater emphasis on social interactions. Leach and Scott (2000) have argued that personal constructivists have not included the social characteristics of the learning and teaching milieu that describe the interaction between learners as peers, and between learners and teachers, and how these affect the process of learning. As a result some science educators and researchers (e.g. Aikenhead, 1996; Ogunniyi, 1996; Tobin, 1996; Jegede, 1996) have preferred to use the socio-cultural approach discussed in the next sub-section.

2.3.2 Socio-cultural constructivism

Aikenhead (2000) has observed that, although the social constructivist view of learning with its emphasis on "enculturation" enjoys wide support among science educators, it is however, limited by its pre-occupation to enculturate all learners into western science. He has instead presented a view of school science that emphasizes the interaction between western science and the culture of the learner and argues, "only by taking a pluralistic cultural approach can the goal 'science for all' be attained" (p.245). Further Ogunniyi (1995) has argued that the accumulation of data on "personal construction" of scientific concepts has not brought much progress in terms of helping in the formulation of a comprehensive theory of learning. Besides, it has been realized that learning is context dependent and that what an individual learns is socio-culturally related. Ogunniyi (1996) has argued that although science education is concerned with issues in science, its primary role is essentially socio-cultural, namely the articulation of science in such a way that even a novice in any society can make sense of science. However, he observed that this task was not as easy as it seemed. He asked that if science were the product of the culture that produces it, would it not be incongruous to assume that science can reach conclusions independent of the larger socio-cultural context within which it flourishes? In other words, he asserts that the socio-cultural conditions and political aspirations of a society are likely to influence scientific claims and practice. This view has probably challenged some social constructivists, according to Jegede (1995), to incorporate a social element in concept development. These social constructivists (e.g. Jegede, 1995; Ogawa, 1986; Ogunniyi, 1995) have also indicated that concept development in school science is influenced to a great extent by social factors, especially learners' socially determined preconceptions. This has resulted in yet another form of constructivism, namely, "socio-cultural constructivism".

Sutherland and Dennick (2002) have observed that culture is one factor within the learner's social environment that is an area of interest to social constructivists' examination of science learning. They assert that culture includes the expectations, beliefs, attitudes, language, systems, and values that influence an entire community of people. It provides the rules and guidelines for appraising and interpreting interactions with events, people, or ideas encountered in the everyday life of a community (Shade and New as cited in Atwater, 1996). Further Thijs and Van Den Berg (1995) have asserted that cultural factors relative to learners' alternative conceptions regarding school science include: language, environment, social structure characteristics, traditional values and beliefs, modes of thought and epistemology. According to Valsiner (as cited in Atwater, 1996), culture should be then regarded as an inseparable component of a child's development.

Tobin (1996) has stated that the home is a source of learning cultural knowledge, which includes knowledge of values. He has argued that learners who learn this home-based cultural knowledge might bring it with them to the classroom and use it to make sense of what is happening in science lessons. He further argues that this knowledge could facilitate or hamper the learning of science (e.g. by constraining the way the learners interact with others and engage the activities designed to promote learning). He, therefore, recommends that it would be advantageous for a teacher to be aware of the potential impact, positive or negative, of this cultural knowledge on the learning of science. On the other hand, Tobin (1996) has pointed out that the knowledge acquired by the learners in science lessons "must be viable not only personally, but also in the social contexts in which action occurs" (p.32). In this regard, the teacher as a representative of the society has the responsibility of educating learners, assisting them to learn what is currently regarded by society as viable knowledge. He points out that if a teacher perceives the constructions of any learner as not being viable it is his/her duty to arrange the learning environments such that it facilitates the process of learning what society views as proper at that particular point and time. According to Atwater (1996), this is because much of a person's actions (including knowledge and intentions of the person) can be understood only in terms of the norms of the society in which that person is a member.

George (1999a) proposed a scheme for categorizing cultural knowledge when consideration is being given to using it in the science classroom

- Category 1: the cultural knowledge can be explained in conventional science terms
- Category 2: a conventional science explanation for the cultural knowledge

seems likely, but it is not yet available

- Category 3: a conventional science link can be established with the cultural knowledge, but the underlying principles are different
- Category 4: the cultural knowledge cannot be explained in conventional science terms.

George (1999a) argues that if science educators accept that the constructions of students can involve different categories of background cultural knowledge, then it becomes obvious that the interaction between school science and the students' prior knowledge can be multi-faceted. According to her, background cultural knowledge falling into category 3 and 4 is likely to present the greatest challenge because these types of knowledge seem to conflict with school science.

2.3.3 Constructivism Perspectives Versus Socio-cultural Approaches

Cobb (1994) questioned the assumptions that started the debates about the distinction between constructivism and socio-cultural perspectives. He argued that the two perspectives complement each other, and that they can only be distinguished on the basis of the observational perspectives chosen by a researcher. He argued that from the socio-cultural perspective, the focus of the researcher would be on the "conditions for the possibility of learning" while on the constructivism side, it would be on "what students learn and the processes by which they do so" (p.13). In other words, the focus of the former was on the social and cultural basis of personal experience while from the latter, it was on the constitution of social and cultural processes by actively interpreting individuals. Further more, Driver et al. (1994) have argued that in the constructivism perspective way:

> Making meaning is … a dialogue process involving persons-in-conversation, and learning is seen as the process by which individuals are introduced to a culture by more skilled members…The challenge lies in helping learners to appropriate these models for themselves, to appreciate their domains of applicability and, within such domains, to be able to use them… the challenge is one of how to achieve such a process of enculturation successfully in the round of normal classroom life (p.7)

Smith (1995) suggested that a distinction be made between the terms knowing and knowledge. He proposed that knowing should indicate the subjective meanings of the individual, and knowledge to indicate socially negotiated and accepted forms of language. He argued that with this distinction, the focus of constructivist researchers would be on knowing while the focus of socio-cultural researchers would be on knowledge.

When Cobb (1995) responded to Smith's (1995), he clarified the fact that his version of constructivism was the "emergent perspective" as opposed to the "psychological perspective" discussed by Smith. He argued that the difference in the versions of constructivism had an impact on the constructs they made with socio-cultural theory. According to Smith's version, socio-culturalists would be more interested than psychological constructivists in interactions among individuals while on the other hand; constructivists subscribing to emergent perspectives would focus on interpersonal processes. He further distinguished between psychological constructivism, emergent constructivism and socio-cultural theory by arguing that:

> Psychological constructivists might talk of individual knowing, whereas those who subscribe to the emergent perspective might be concerned with both individuals' socially situated knowing and the take-as-shared ways of knowing constituted by these individuals. Further, although socio-cultural theorists frequently speak of shared knowledge, they also stress that it is dynamic and evolves historically. In addition many emphasize that thought is an activity or process. They might therefore be open to the notion of shared knowing and focus

on its role in generating individual knowing (p. 26)

When responding to Smith's article, Driver and Scott (1995) argued that their position was not located exclusively with either personal constructivism or with socio-cultural approaches. For them a complex issue that was at stake was the interaction between personal knowledge and knowledge as a social construction. They stated that their stand was Vygotskian and argued that

> To suggest the "constructivist researchers would have a primary focus on knowing whereas socio-culturalists would focus primarily on knowledge" appears unduly separatist; a Vygotskian socio-cultural perspective does not separate individual cognition from its socio-cultural origins and would therefore necessarily be interested in both knowledge and knowing (Driver and Scott, 1995:28)

2.4 THE WORLDVIEW THEORY AND THE SOCIO-CULTURAL ENVIRONMENT

Jegede (1997b) asserted that, since every society educates its younger generation to pass down the socio-cultural attributes of its people, the socio-cultural factors within a non-western society become a composite part of the environment. In the light of this, Jegede and Okebukola (1989, 1991a, 1991b) and Okebukola and Jegede (1990) embarked on a number of studies to discover the types of socio-cultural factors prevailing in a Nigerian setting. Their findings led them to conclude that there are five predictors of socio-cultural influences on the learning and teaching of science in Nigeria, namely: authoritarianism, goal structure, traditional worldview, societal expectations and sacredness of science. According to Jegede (1997b), these studies have led them to the following conclusions:

- That the socio-cultural background of the learner may have a greater effect on education than the content.

- That reasoning that is based upon a non-western worldview with its attendant socio-cultural factors inhibits the initial adoption by a student of western science empirical methodology as well as the acceptance of the evidence from such a methodology.
- The non-western worldview seems to cause a student to become involuntarily selective when making observations in a science classroom
- Knowledge learnt through school science and traditional environment is compartmentalized and drawn upon to explain any phenomenon, depending on the particular situation.

These conclusions, first of all, imply that any western science curriculum in a non-western classroom ought to take into consideration the traditional worldview of the learner. Traditional worldview, according to Sutherland and Dennick (2002) is subsumed under the "beliefs" category of Phelan et al.'s (1991) definition of culture that specifies that culture is the norms, values, beliefs, expectations and conventional actions of a group. What is more, Allen and Crawley (1998) have argued that the worldview theoretical model is a powerful way of understanding the conflicts in cross-cultural teaching. Proper et al (1988) have added that the concept of worldview is central to education because it is closely related to the concept of knowledge acquisition (i.e., learning). By examining the way in which the scientific ways of thinking are integrated into other beliefs, science educators may more successfully separate ways of thinking and acting which are essential to the nature and practice of science from those, which are cultural artefacts, which may hinder science learning. Further Cobern (1996b) has proposed the use of the worldview concept since it is:

> ...About metaphysical levels *antecedent* to specific views that a person holds about natural phenomena, whether one calls these views common-sense theories, alternative frameworks, misconceptions, or valid science. A worldview is the set of fundamental non-rational presuppositions on which these conceptions of reality are grounded...my assertion (is) that a scientific worldview, or as I prefer a scientifically compatible worldview, is a major goal for science education" (Cobern, 1996b p.585)

According to Ogunniyi (1995) this first implication would, from a constructivist perspective, challenge the science teacher on how to focus on student learning with understanding rather than content coverage.

Secondly, the conclusions made above also imply that it is possible for a non-western student to perform well in a western classroom without imbibing or being enthusiastic about displaying the associated values and attitudes. In an attempt to explain this phenomenon, several theories/hypotheses have been proposed by a group of science educators to explain how learners move between their everyday life worlds and the world of science, and how they deal with cognitive conflicts between these two worlds (Aikenhead, 1996; Jegede, 1995; Ogunniyi, 1995). The following subsections will briefly define and discuss these theories/hypotheses, namely, Cultural Border Crossing theory, the Collateral Learning theory, and the Contiguity Learning hypothesis.

2.5 THE WORLDVIEW THEORY AND CULTURAL BORDER CROSSING

Cobern (1996b) and Aikenhead (1996) have brought anthropological methods and perspectives into science education discourses, although with slightly different emphasis. Aikenhead (1996) has argued that science educators' perspectives on how students make sense of their world widens even further if they consider the worldviews that students possess. This is because worldviews provide a special possibility structure of ideas, activities, and values that allows one to gauge the plausibility of any assertion. Since worldviews are culturally based, to understand a learner's worldview is to anticipate which meanings in a science a science curriculum will appear plausible and which will not. Cobern (1996b) concurred. For him, if worldview is treated as a culturally influenced organization of the mind, worldview theory suggests a broader perspective of science education: where learning is seen as cultural acquisition. According to Aikenhead (1996), this perspective is a practical extension of constructivist theories and plausibility structures.

2.5.1 The Cultural Perspective of Science Education

A cultural perspective on science education views teaching as cultural transmission and views learning as culture acquisition where culture, according to Geertz as cited in Aikenhead (1997), means "an ordered system of meaning and symbols, in terms of which social interaction takes place". Aikenhead (1997) has argued that anthropologists Phelan, Davidson and Cao have given more specificity to Geertz's definition of culture by conceptualising it as the norms, values, beliefs, expectations, and conventional actions of a group. According to Aikenhead (1997), even though different science education studies have used different aspects of culture to highlight particular interests in cultural education, Phelan et al's (1991) definition is advantageous because it has fewer categories. What is more, these categories can be interpreted broadly to encompass anthropological aspects of culture as well as the educational attributes often associated with science instruction such as knowledge, skills and values. For this study canonical scientific knowledge have been subsumed under "beliefs" in Phelan et al's (1991) definition. According to Aikenhead (1996), within every culture group there exists subgroups. Each identifiable subgroup is comprised of people who generally embrace a defining set of norms, values, beliefs, expectations, and conventional actions. Each subgroup shares a culture designated as subculture. A person can belong to several subgroups at the same time and large numbers and many combinations of subgroups exist due to the associations that naturally form among people in society. Aikenhead (1996) has argued that science itself is a subculture of Western or Euro-American culture. It also has a well-defined system of norms, values, beliefs, expectations, and conventional actions that are generally shared in various ways by communities of scientists. Hence science satisfies the definition of culture. According to Aikenhead (1997), descriptions of the subculture of science often include the following attributes: mechanistic, materialistic, reductionist, empirical, rational, de-contextualized, mathematically idealized, communal, ideological, masculine, elitist, competitive, exploitative, impersonal and violent.

Closely aligned with western science is school science, whose main goal has been cultural transmission of both the subculture of science and the dominant culture of a country. Aikenhead (1996) has argued that school science expects a learner to acquire the norms, values, beliefs, expectations, and conventional actions of science and make them part of his or her personal world to varying degrees, as well as to acquire the community's dominant culture. In this way, students' understanding of the world can then be viewed as a cultural phenomenon, and learning at school as culture acquisition. This means that school science traditionally attempts to enculturate or assimilate students into the subculture of science. It is a potent cultural force in any society, a force that impinges upon most students daily.

According to Aikenhead (1996), the cultural perspective of science education recognizes conventional science teaching as an attempt at transmitting a scientific culture to students. Aikenhead (1997) has further argued that transmitting a culture can either be supportive or disruptive to students. If the subculture of science generally harmonizes with a student's life world culture, science instruction will tend to support the student's view of the world, and the result is *enculturation*. If the subculture of science is generally at odds with a student's life world culture, science instruction will tend to disrupt the student's view of the world by trying to replace it or marginalize it. The student will be forced to abandon his or her indigenous way of knowing and a new (scientific) way of knowing will be reconstructed in its place. The result of this, according to Aikenhead (1997), is *assimilation*. Knain (1999) has argued that it is when assimilation is attempted that science may be ignored as without meaning or relevance to the student. The student may then develop tricks to memorize scientific content without believing it. Alienation then becomes the result. To avoid alienation, Aikenhead (1997), has proposed that science educators encourage students to become skilled at cultural border crossing.

2.5.2 Cultural Border Crossing

A lot of recent literature has adopted a cultural view towards science education in that it constitutes science teaching as a cultural activity in the contrived classroom situation (e.g. Aikenhead, 1996; O'Loughlin, 1992). This cultural perspective, according to Aikenhead (1996), recognizes conventional science teaching as an attempt at enculturisation or assimilation. To Aikenhead (1996) and Adams (1999) enculturation is a process by which a learner accommodates school science into his/her cosmology while retaining his/her sense of identity. Assimilation on the other hand, is the process of subsuming his/her worldview to that of science. In that case he/she so to speak abandons his/her traditional worldview to that of science. The learner's experiences with school science are considered in terms of students "crossing borders" from the sub-cultures associated with his/her socio-cultural environments into the sub-cultures of science. To acquire the culture of science, Aikenhead and Jegede (1999) assert that students must intellectually shift from their everyday life-world with its traditional world-view suppositions to that of school science. Obviously there are bound to be conflicts. There is a plethora of studies that have reported such conflicts between the ethno-science or what have been "children science", "naive science", "alternative worldviews", etc (e.g. Ogunniyi et al, 1995).

Aikenhead and Jegede (1999) have pointed out that the capacity to think differently in diverse cultures and the capacity to resolve conflictions between those cultures are familiar human traits. They have argued that these capacities are, however, not equally shared among all pupils. Aikenhead and Jegede (1999) have claimed that it was Phelan, Davidson and Cao (1991) who discovered this when they investigated students' movements between worlds of families, peer groups, school and classroom. Phelan et al's (1991) data has described different border crossings such as: *smooth, managed, hazardous and impossible*. Costa (1995) has provided a link between Phelan et al's (1991) anthropological study of schools and the specific issues faced by science educators. She has studied students' varied success at moving between the culture of their families and the culture of their science classroom. She has categorized students according to their ease of transition based on empirical data from diverse high school science students in California. Costa's (1995) categories were as follows: *potential scientists* whose worlds of family and friends were congruent with worlds of both school and science; *other smart kids* whose worlds of family and friends were congruent with world of school but inconsistent with world of science; "*I don't know*" students whose worlds of family and friends were inconsistent with worlds of both school and science; *outsiders* whose worlds of family and friends were discordant with worlds of both school and science; and *inside outsiders* whose worlds of family and friends were irreconcilable with the world of school, but were potentially compatible with the world of science.

According to Aikenhead (1996), Phelan et al's (1991) and Costa's (1995) models of students' multiple worlds have helped in exploring how students move from one world to another. Their categories have helped in clarifying some critical issues that science education researchers face when they consider the consequences (for the curriculum) of a cultural perspective for science education. He considers a learner's experiences with school science in terms of "crossing borders" from the sub-cultures associated with the learner's socio-cultural environments into the sub-cultures of science. Culture is defined as the norms, values, beliefs, and convectional actions of a group. To acquire the culture of science, a learner should intellectually shift from his/her everyday life-world with its traditional world-view suppositions to that of school science, which might obviously result in conflicts

Knain (1999) has argued that border crossing is a practical approach to achieve a culturally sensitive science education that is rooted in Aikenhead's framework. For him, cultural border crossing means that students can cross the border between their everyday thinking and science without being forced to assimilate science, that is, a no-assimilation rule is applied. Aikenhead (1996) has argued that both enculturation and assimilation require cultural border crossing into the subculture of science. As students move from one subculture to the other, they intuitively and subconsciously alter certain beliefs, expectations, and conventions. According to Knain (1999), border crossing could be achieved by switching language, values and epistemologies explicitly when crossing the borders.

Aikenhead (1996) has adopted Phelan et al's (1991) four types of border crossing between the learner's traditional worldview and that of school science, namely: smooth, managed, hazardous, and impossible border crossings. He argues that Phelan et al's (1991) definition is used because it has a relatively small number of categories (viz family, peer groups, classrooms and school) "… that can be interpreted boldly to encompass the anthropological attributes of culture and the educational attributes often associated with science instruction: knowledge, skills and values" (Aikenhead, 1996:8)

When the students' worldviews are congruent with school science, the students experience a smooth border crossing between their worldviews and that of science. Managed border crossing occurs when the learner's worldview is different from the science worldview thus requiring the transition from one to the other to be managed. According to Aikenhead and Jegede (1999), the way such a learner acquires this foreign content makes it accessible to him or her whenever he or she needs to achieve such social goals as talking with his or her teacher or passing examinations, even though that knowledge may contradict or seem irrelevant to his or her traditional worldview. According to Aikenhead (1996) such a learner sees science courses as more fact-oriented and memorization-oriented than other non-science classes.

Hazardous border crossing occurs when the learner's worldview and science worldview are diverse leading to hazardous transitions from one worldview to the other. Aikenhead and Jegede (1999) have argued that the learners that attempt hazardous border crossings usually "do not want to look stupid at school, and so they are motivated to do as well as they can. They generally resist being assimilated into the culture of science, but their lack of academic savvy tends to limit their success at school science" (p271). Aikenhead (1996) adds that the learners who undergo hazardous transitions pass a course without understanding the content, and that "pose little problems as long as the teacher does not "expect them to replace their commonsense conceptions with self-constructed knowledge or engage in scientific inquiry other than going through the motions of getting the right answer" (p18)

Impossible border crossing occurs when the learner's worldview and that of science are highly discordant causing students to resist transitions from one worldview to the other. The learners, according to Aikenhead and Jegede (1999), experience "such a discordant culture gap" between their socio-cultural environment and school science that moving into the school science worldview becomes virtually impossible.

Aikenhead (1996) also observed that the science education's goal of cultural transmission runs into ethical problems in a non-Western culture where western thought is forced upon students who do not share its system of meaning and symbols. To Aikenhead and Jegede (1999), students in the developing countries eventually feel that school science is like a foreign culture to them and that this feeling stems from the fundamental differences between the western culture of science and their indigenous culture. Aikenhead (1996) also stated that when the culture is at odds with the students' life-world, science instruction tends to disrupt the students' worldview by trying to force that student to abandon or marginalize his or her life-world concepts and reconstruct in their place new scientific ways of conceptualising natural phenomena. On the other hand, Ogunniyi (1988) suggests that the aim of science education should not be to supplant or denigrate a traditional culture but should be to help the pupil meet modern challenges. He argues further that if the scientific worldview is to succeed in Africa, the aim should be geared towards accommodation rather than assimilation.

2.5.3 Cross Cultural Science Education

Research studies into the difficulties of non-western students studying western science have identified obstacles experienced by students who have an indigenous/ traditional background and attempt to learn a subject grounded in western culture (Okebukola and Jegede 1990; Jegede and Okebukola 1991a and 1991b). Aikenhead (1996) has argued that science education's goal of cultural transmission runs into ethical problems in a non-western culture whose western thought is forced upon students who do not share its system of meaning and symbols.

According to Cobern (1996a), the teaching and learning of science is often a cross-cultural activity. He has argued that a classroom lesson seeking to make scientific sense of a science concept becomes a cross-cultural activity when the scientific sense does not fit automatically with the students' more global view of reality. For him, the further students are culturally removed from the West the more seriously science educators have to address the relevance of culture in science education. He has further argued that it was important for science educators to understand the fundamental, culturally based belief about the world that students bring into class, and how these beliefs are supported by students' cultures, because science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural milieu of students. He has contended that the problem in non-western science education was not to make it more scientific, but to make it less culturally western. Wilson cited in Cobern (1996a) has concurred. According to Wilson, for science education to be effective, it must take much more explicit account of the cultural context of the society which provides its setting, and whose needs it exists to serve. Cobern (1996a) has continued to argue that with respect to non-western cultures, this has suggested that a simple transfer of western educational practices to other cultures would not do. "Transfer should not occur without first adapting curricular for the receiving country. Curricula would have to be adapted to remove an American cultural bias and substitute an African cultural bias" (p.298). Cobern (1996a) then went on to suggest that researchers could use a constructivist model of learning to both support the need for, and facilitate, investigations of how science education could be formulated from different cultural perspectives.

On the other hand, Aikenhead (1996) has argued that, because the subculture of science tends to permeate the culture of those who engage it, curriculum specialists and teachers need to develop a curriculum that explicitly eschews assimilation and vigilantly circumvents unwanted acculturation. He has suggested that an ideal goal for science education would be to help learners to master and critique scientific ways of knowing without, in the process, sacrificing their own personally and culturally constructed ways of knowing. He has further argued that to achieve this would depend on the ease with which students are able to cross cultural borders. One curriculum implication for this would be to develop instructional materials that:

- Make border crossing explicit for students
- Facilitate border crossing
- Substantiate the validity of students' personally and culturally constructed ways of knowing
- Teach the knowledge, skills and values of western science and technology in the context of societal roles.

According to Aikenhead (1996), a cross-cultural perspective for science curriculum suggests that learning results from the ever-changing interaction among: personal orientation of a student; the subcultures of a student's family, peers, tribe, school, media, and so forth; the culture of his/her nation; and the subcultures of school and school science.

Aikenhead (1997), when exploring the First Nations (Native Americans) science education from a cultural perspective, proposed a cross-cultural STS school science curriculum that involves: *enculturation, autonomous acculturation* and *anthropological instruction*. He explained that the *enculturation* of First Nation students in a cross-cultural science course would relate to the cultural transmission of Aboriginal content where science content would not be transmitted by enculturation. *Autonomous acculturation* would be the process of intercultural borrowing or adaptation in which one borrows or adapts attractive content or aspects of another culture and incorporates (assimilates) it into one's indigenous culture. He claimed that under this process *outsiders* could be changed into "*I Don't know*" or *Other Smart Kids*. On the other hand, *Anthropological* Instruction would be the process whereby a student of subculture science is similar to an anthropologist learning the ways of a foreign culture. He claimed that this process would be suitable for *Potential Scientists* and *Other Smart Kids*.

Aikenhead (1997) has argued that a cross-cultural STS science curriculum would:

> Emphasize cultural border crossing for the purpose of enhancing students' capabilities and motivations to eclectically draw upon the subculture of science and technology, for the purpose of taking practical action toward economic development, environmental responsibility, and cultural survival (p.229).

He further pointed out that border crossing within a cross-cultural STS might be facilitated by:

- Studying the subcultures of students' everyday lives
- Contrasting those subcultures with a critical analysis of school science (norms, beliefs, expectations, values, and conventional actions)
- Consciously moving back and forth between the everyday world and the science world by switching explicitly the following: language conventions, conceptualisations, values and epistemologies, but never expecting students to adopt a scientific way of knowing as their personal way.

Aikenhead (1997) has explained that in cross-cultural STS science education, students and teachers become cultural border crossers between First Nations cultures and the cultures of science. Teachers facilitate in their role as tour guide, travel agent, or culture broker and in this way "help students feel that the school program is a natural part of their lives and help them move more smoothly back and forth between one culture and the other" (p.232)

Although the Border Crossing Theory has been able to identify the different types of border crossings experienced by learners in the science education enterprise, it has, however, not provided a description of *how* the learner undergoes the transition from one worldview to another. What is more, the categorisation of learners into *potential scientists, other smart kids, "I don't know"* and *outsiders* gives one the impression that these categories are fixed, hence denying the learners the chance of changing from one to the other. This also implies that learning in science is a process that is not dynamic. Further more, the construct has not considered the issue of language, which plays a very important role in the acquisition of science concepts.

2.6 THE WORLDVIEW THEORY AND THE COLLATERAL LEARNING THEORY

Jegede (1995) has proposed the Collateral learning Theory as a mechanism to explain how a learner harmonizes the conflict resulting from a traditional worldview and that of science. Jegede (1997b) defines it as "the process whereby a learner in a non-western classroom constructs, side by side and with minimal interference and interaction, western and traditional meanings of a simple concept" (p.10). Jegede (1995, 1996, 1997b) states that there are variations in the degree to which the conflicting ideas interact with each other and the degree to which conflicts are resolved and has identified four types of collateral learning, namely: parallel, secured, dependent and simultaneous collateral learning. These types are not separate categories, but points along a spectrum depicting degrees of interaction and resolution.

In the parallel collateral learning type, the conflicting schemata do not interact at all. Students will access one schema or the other depending on the given situation, i.e. the learners will use a scientific concept only in school, and never in their everyday world where commonsense concepts prevail.

In secured collateral learning, the conflicting schemata consciously interact and the conflict is resolved in some manner. The person will have developed a satisfactory reason for holding on to both schemata even though the schemata may appear to conflict, or else the person will have achieved a convergence toward commonality by one schema enforcing the other, resulting in a new conception in long-term memory, i.e. students are able to resolve the conflict between two schemata by actively considering both schemata and coming up with good reasons for holding both.

In dependent collateral learning, the schema from one worldview or domain of knowledge challenges another from a different worldview or domain of knowledge, to an extent that permits the student to modify an existing schema without radically restructuring the existing worldview or domain of knowledge. According to Aikenhead and Jegede (1999), a characteristic of dependant collateral learning is that students are not usually conscious of the conflicting domains of knowledge, and consequently, students are not aware that they move from one domain to another (unlike students who have achieved secured collateral learning). It occurs when a student's preconception or indigenous belief is: (a) contrasted with a different conception encountered in the science classroom; (b) given a tentative status, and then either; (c) altered by reconstructing the original schema under the influence of the newly encountered schema; or (d) rejected and replaced by a newly constructed schema. In other words, students reject or modify their original schema because it makes sense to do so. From the cultural anthropology, dependent collateral learning is the cognitive explanation for acculturation - the selected modification of currently held ideas and customs under the influence of another culture. Some subjects started off by explaining events both using traditional worldview or scientific worldviews and ended up using the other after the intervention or after a discussion with others.

Simultaneous collateral learning fits between parallel and dependent collateral learning. A situation can occur in which learning a concept in one domain of knowledge or culture can facilitate the learning of a similar or related concept in another milieu. In the two settings (home and school), learning about a concept is not usually planned, but arises spontaneously and simultaneously. By reflecting on the two settings and their concomitant concepts, a student may easily cross the cultural border between home and school science. The two sets of schemata established in long term memory by simultaneous collateral learning may overtime: (a) become further compartmentalized, leading to parallel collateral learning; or (b) interact and be resolved in some way, resulting in either dependent or secured collateral learning, dependent on the manner in which the conflict is resolved.

The theory of collateral theory seems to have received increased attention in the literature. For example, Driver (1983) makes a distinction between pupils' point of view and school science by stating the possibility and importance of understanding alternative interpretations, "to those suggested by other pupils or scientists, without necessarily believing any of them (p.81)". This is what Ogunniyi (1988) calls harmonious dualism. According to this theory a students' traditional cosmology that is not acceptable to a western science does not necessarily preclude an understanding of science when she/he enters a science class. He concludes that it is possible for a learner to hold the scientific and a traditional view of the world simultaneously without suffering cognitive dissonance in much the same way that Western scientists hold Science and Christianity. Recently he proposed the contiguity hypothesis to explain his view about harmonious dualism (see Ogunniyi, 1995; 1996). This will be presented later.

2.6.1 Border Crossing and the Collateral Learning Theory

Aikenhead and Jegede (1999) have argued that collateral learning and border crossings are fundamentally interrelated because effective collateral learning in science classrooms will rely on successful cultural border crossings into school science. They have also claimed that the collateral learning theory is a cognitive explanation for the cultural phenomenon (conflicts between worldviews and cultures) mediated by transitions or border crossings between students' cultures and that of science. In a table summarizing the relationship between cultural border crossing, collateral learning and implications for teaching, Jegede and Aikenhead (1999) claim that there is a relationship between:

- Smooth border crossing and parallel, secured or no collateral learning.
- Managed border crossing and parallel, simultaneous, or secured collateral learning
- Hazardous border crossing and either dependent or simultaneous collateral learning
- Impossible border crossing and possibly dependent, if at all.

Even though the Collateral Learning Theory has aptly identified the different types of collateral learning experienced by a non-western learner, it has, however, not described how the learner acquires each one of them. It is also not clear whether or not a learner remains fixed in one type of collateral learning or he/she can move from one to the other, depending on the concept being learned. Once again, the issue of language has not been dealt with as was in the case the Border crossing Theory.

2.7 THE WORLDVIEW THEORY AND THE CONTIGUITY LEARNING HYPOTHESIS

Adams (1999) observes that Ogunniyi (1995; 1996) has slightly changed his harmonious dualism hypothesis into what he (Ogunniyi, 1988) "Contiguity Learning Hypothesis". Ogunniyi (1996) proposed the contiguity-learning hypothesis as a bridge principle to depict

> How two or more co-existing or successive mental states dynamically not only recall, relate, collaborate, but also compete, supplant or dominate one another in the learning process depending on the worldview template serving as a frame of reference in a given context (Ogunniyi 1996, p.92)

Ogunniyi (1996) suggests that two or more apparently contradictory worldviews are repositioned such that they ultimately lie contiguously. Their level of overlap will depend on effectiveness of the adaptive mechanism on the one hand, and the degree of equilibrium between or among the conflicting worldviews, on the other. The degree of equilibrium will, of course, depend on the suitability at the points of "contact" in terms of overall psychological, mental and emotional state experienced by an individual. Adams (1999) likens the process to a wrestle between two worldviews, which is eventually won by the dominant one. He cites Ogunniyi (1995) as asserting that

The competing worldviews not only find a template at the point of contiguity, they ultimately collaborate with each other to engender a complex and a more elaborate worldview structure capable of accommodating the new experience. The individual may still hold a traditional outlook to retain his/her sense of identity but he/she is now aware and may even use in a given context, perspectives distinctly different from his/her own (p.18)

Ogunniyi (1988) construes the process valid enculturation as opposed to assimilation whereby a worldview is completely abandoned in favour of a new one. The latter, according to Adams (1999), occurs when an individual capitulates and rejects his/her culturally acquired worldview for the new one on a permanent basis.

In recent publications the Contiguity Learning Hypothesis has been restructured such that it draws from various sources such as the philosophic, linguistic, and psychological literature (Ogunniyi, 2002b). It has also tapped from the field of neural science, which regards the neural network as a basis for learning and memory (Ogunniyi, 2002a). It also adopts the constructivists' view that learners "enter into the science classroom with relatively well formed intuitive and commonsensical ideas about the world around them" (Ogunniyi, 2002b: 7). The hypothesis assumes that a student learns by crossing borders between two worldviews that have been related to each other. The success of this activity will depend on how the student will intellectually steer between the two thought systems. Ogunniyi argues that

> The hypothesis here is that at the micro or cellular level, the "bridging" process requires that a set of neurons (influenced by the two thought systems, particularly their dominant or representative schemata) converge and exchange certain electrical and chemical "messages" resulting (metaphorically speaking) in the evolution of various levels of conflicts or conceptualisations such as: different types of collateral learning or border crossings, depending on the compatibility or otherwise of the domineering schema in a given context (Ogunniyi, 2002a: 8)

From the foregoing, it seems Ogunniyi (2002a) sees an overlap between his hypothesis and the theories propounded by Jegede (1995) and Aikenhead (1996). This will be investigated later in the following section and in chapter five.

2.7.1 Border Crossing and the Contiguity Learning Hypothesis

On the other hand, Ogunniyi (1997) has argued that while a number of theories and hypotheses (e.g. the "Collateral Learning Theory" by Jegede, 1995; the "Cognitive Conflict Model" by Ogawa, 1986; and the "Harmonious Dualism Hypothesis" by Ogunniyi, 1988) have provided a useful description of how learners relate their traditional worldviews and that of school science, they have not gone deep enough to explain the actual mechanisms or processes of border crossing. He has since posited "the Contiguity Learning Hypothesis as a plausible explanatory model for cognitive border crossing" (Ogunniyi, 2002b, p.1). According to Ogunniyi (2002b), the Contiguity Learning Hypothesis:

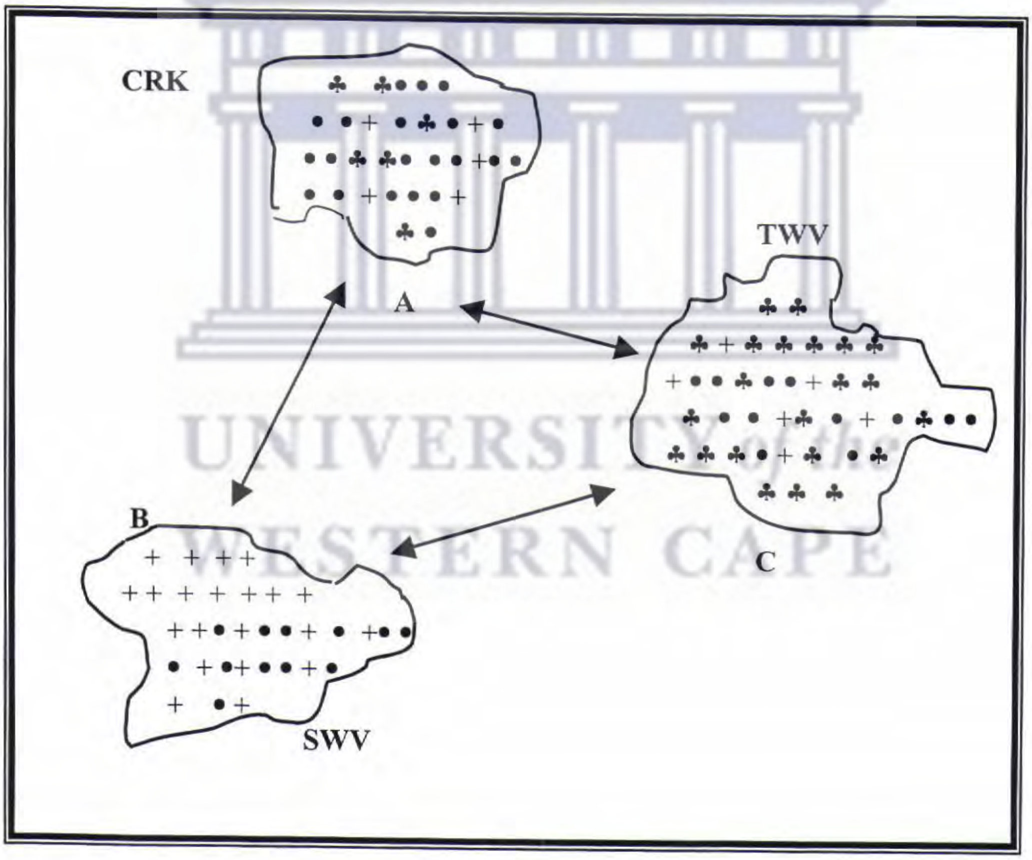
> "Construes border crossing as a dynamic, non-linear intellectual process triggered by contiguously interacting worldviews schemata resulting in a massive convergence of neural network and hormonal activities directed at cognitive restructuring and adaptability... It regards border crossing as a learning process evinced by the interacting worldview schemata in a given context. The context itself is the product of dynamic physico-chemical reactions as well as psycho-metaphysical schemata or embodied experience regulating the whole process. The physical aspect of this interaction is explainable in terms of neural and hormonal activities while the psycho-metaphysical aspects relate to the interest shown. (Ogunniyi, 2002b, p8-9)

Ogunniyi (2002b) further claims that the type of border crossing that will result from the "bridging mechanism" between the two thought systems will depend on "the influence of the dominant worldview presuppositions or assumptions at work and the human interest being served" (p.9).

The construct assumes that the cognitive apparatus of the learner as well as his/her entire body are involved in the process of learning. It assumes that a learner's cognitive structure consists of three basic worldview schemata: traditional beliefs, commonsense – intuitive knowledge and science – all derived from his/her culture, school and life worlds as a whole (see Fig. 1). Each schema consists of elements of the other two schemata to a greater or lesser degree. All the three major schemata are in a state of dynamic flux and all are activated by contextual circumstances in which an individual finds him/herself or the interest to be served. The three worldviews come against each other or align with each other and naturally seek points of contiguity (i.e. regions in the thought systems sharing common elements) in order to accommodate, reconcile and adapt to each other. The contiguous "sites" are comparable to what Ausubel (1968) would call subsumers, which act as anchors to link contiguously distinct thought systems together. Now, the process of seeking harmony or equilibration is triggered off by the physico-psychological context created by the contiguously interacting schemata. The task of constructivist instruction is to determine what the learners know (in terms of elements critical to meaningful interaction) in order to facilitate the points of contiguity.

The schemata constituting an individual's cognitive structure align contiguously to represent the presumably best disposition warranted by the occasion in question.

However, in doing so, his/her entire body, together with the neurological, psychological and metaphysical aspects of his/her being are mobilized to predispose him/her to adopt a mentality or behaviour presumed to be appropriate or compatible to a given context. The structuring and the re-structuring of the basic elements of the schemata (i.e. a form of micro "brain storming" among the interacting schemata) together with the bodily response to a given context is what the Contiguity Hypothesis attempts to explain. The role of language in the cognitive repertoire for input and retrieval of information for this structuring – restructuring process cannot be overstated. But this is another level of analysis altogether (Ogunniyi, 2002b).



Key: • **CRK** Commonsense (rational) knowledge; + **SWV** Scientific worldview;
♣ **TWV** Traditional worldview

Fig. 1: Thought systems seeking "points" or "state" of contiguity
(Source: M.B. Ogunniyi (2002b) Border Crossing into School Science and the Contiguity Learning Hypothesis. NAST Conference. p.198)

Unlike the Border Crossing and Collateral Learning Theories, the Contiguity Learning Hypothesis has been able to describe in general terms how the transition from one worldview to the other is likely to occur. However, it has been unable to spell out how and under what conditions the different types of border crossings and collateral learning are likely to be acquired by a non-western learner. Also, like in the case of the other two constructs, the Contiguity Learning Hypothesis has not deliberated on the issue of language.

2.8 STUDIES ON WORLDVIEW THEORY

A perusal of literature has revealed some research studies that have been conducted to determine how worldview and cultural beliefs and practices affect learning. The sub-sections that follow will explore these studies and highlight their implication for curriculum planning and instructional practice particularly with respect to conceptual change.

2.8.1 Worldview theory and the socio-cultural environment

According to Jegede and Okebukola (1991b), the dominance of either the anthropomorphism (or traditional) or mechanism (or science) worldviews in any society is dependent on the socio-cultural structure of that society. The socio-cultural grouping of individuals in such a society is characterized by a commonality in values and an appreciation of beliefs, customs, myths and so forth. They have further argued that these characteristics, amongst many other factors, regulate the everyday life of persons within the traditional society and consequently govern their view of natural phenomena. They contend that, in every society spirited efforts are made to pass on to the younger generation the knowledge, skills and values of that society. The survival of any society seems to depend on its ability to communicate its "library of knowledge" (Ogunniyi, 1996) to the younger generation. Dewey (1944) put it quite succinctly when he asserted that

> ...There is the necessity that these immature members be not merely physically preserved in adequate numbers, but that they be initiated into the interests, purposes, information, skill, and practices of the mature members: otherwise the group will cease its characteristic life (p. 3)

In a world dominated by science it has become necessary even in an essentially traditional society to incorporate the scientific worldview into the overall cosmological view of that society to enable it to adapt better to a rapidly changing eco-cultural environment. It is for the same reason that Ingle and Turner as cited in Baker and Taylor (1995) have called for a curriculum that maintains a sensible balance between school science and the socio-cultural beliefs of students in non-western societies. As Ogunniyi (1988) and Gunstone and White (2000) have remarked the issue is no longer one of abandoning one for another but that of incorporation, so that the two worldviews co-exist.

A few studies have been carried out to study the worldviews of non-western societies. For example, George (1999b) carried out an investigation on some of the traditional practices and beliefs operating in the daily lives of villagers in a particular setting in the Republic of Trinidad and Tobago. Her aim was to gain an understanding of these beliefs and the interpretive framework that underpins them and to also explore how these might impinge on the learning and teaching of science. Her research was guided by Kearney's worldview theory. The findings of the study showed that the villagers of Seablast had a worldview in which the survival of the *self* was a priority. They were concerned with how to take good care of the *self*. They interacted with the environment (the *other*) for the enhancement of the *self*'s health. *Classification* was carried out on various aspects of the world that they regarded as having effect on their well being. Their views of space and time included the lunar cycle, distances of islands and depths of the sea. *Relationship* was viewed as between *self* and other human beings and *causality* as an outcome of the interaction with the *other*.

Kawagley, Norris-Tull and Norris-Tull (1998) have also explored the traditional worldview of the Yupiaq people of South-western Alaska. They found that Yupiaq ways of thinking about the world reflected a worldview distinct from the western way of thinking. For the Yupiaqs, scientific knowledge is not separated from other aspects of daily life and is not divided into different fields of science. Their worldview is ecological and spiritual. Their concepts and word thoughts are often ineffable because they are based on feelings of connectedness and relationship. Kawagley et al (1998) argued further that the Yupiaq's view of the world is composed of five elements: earth, fire, water, and spirit, which resulted in an awareness of the interdependence of humanity with the environment, a reverence for and a sense of responsibility for protecting the environment.

Ehindero (1982) investigated the effects of certain eco-cultural factors on operational thought among some Nigerian Adolescents living in non-Western Cultures. The results obtained supported the hypothesis that individuals living in a very simple environment, who are nomadic and predominantly hunters, develop spatial skills that are adapted to the ecological demands of their lives and adapted to their 'profession'. Trying to teach science to the beginning learners may in fact be synonymous with an attempt to disrupt some of the cultural beliefs they had lived with for some time under the influences of their eco-cultural framework. Ehindero has argued that confronting the individuals with concrete materials that will presumably allow them to use their multi-sensory modalities to conceptualising in an attempt to be operational may not be the central theme in this situation.

When Lee (1997) investigated the factors that influence science learning with Asian American learners, she found that Asian American learners coped with cultural differences between home and school because their parents expected them to obey the authority of teachers, to work hard, to succeed academically, and to behave well in public. However, their academic success came with high costs because they felt pressured to meet the high expectations of their parents and teachers in academic achievement. A negative consequence of this pressure was that many of these Asian American learners became high achievers with good grades, but passive learners who avoided risk taking or creative process – attributes that are important for advancement of scientific and technological fields. Academic achievements led to emotional, mental, and socialization problems associated with continuous stress related to high achievement.

Lee (1997) also discovered that there was a difference between the Asian American worldview and that of science. The scientific worldview is based on the western tradition of seeking to understand how the world works (i.e. predict, describe, explain and control natural phenomena) which differs from other ways of knowing based on personal beliefs, myths, religious values and supernatural forces. On the other hand, the worldviews of Asian cultures are based on ancestral spirits and the world of the spirits, combination of ancestral worship and aniministic beliefs in spirits, and traditional religious attitudes; natural phenomena based on myths, religious rituals, legends and folktales. Lee argued that the cultivation of the scientific worldview could pose a serious challenge to the Asian Americans. She observed that the concepts of science, nature, and knowledge have different meanings between Asian American and western cultures. In Western culture, the role of science is to master the laws of nature and to use this knowledge through experimental manipulations and control for the good of humans. In contrast, Asian American culture views nature as something to be appreciated and revered, to coexist with humans, and to be associated with the supernatural. What is more, in Asian worldview, the way of knowing or that criterion for the validity of knowledge about nature is often the authority of knowledge sources, be it religious, myths, legends, ancestors or elders, rather than experimentation or observation of natural phenomena. Lee argued that serious conflicts could occur when one cultural view is imposed upon the cultural views of other groups, resulting in the alienation or active resistance of the members of those groups in science.

In another study Aikenhead (1997) summarized the First Nation's (Native Americans) knowledge of nature by using data from different authors. Table 1 below, which is a summary of Aikenhead's article, shows some of the contrasts between the Aboriginal and western scientific knowledge. Concerning Aboriginal epistemology, Aikenhead (1997) added that Battiste has explicated it further by giving detail to what Pomeroy called "nature voices" as he described two traditional knowledge sources. The first source is the immediate world of personal and tribal experiences, that is, one's perceptions, thoughts, and memories that include one's shared experiences with others. The second source is the spiritual world evidenced through dreams, visions, and signs that are often interpreted with the aid of medicine men or elders.

Table 1: Contrast between Aboriginal Knowledge and Scientific Knowledge

(Source: Aikenhead, G.S. (1997). Towards a First Nations Cross-Cultural Science and Technology Curriculum. *Science Education*, 81, 217-233)

Aspects of knowledge	Aboriginal knowledge about the natural world	Western scientific knowledge
Social goals	Survival of a people	The luxury of gaining knowledge for the sake of knowledge and for power over nature and other people. (Peat, 1994)
Intellectual goals	To coexist with mystery in nature by celebrating mystery	To eradicate mystery by explaining it away. (Ermine, 1995)
Association with human action	Intimately and subjectively interrelated	Formally and objectively decontextualized. (Pomeroy, 1992)
Time	Circular	Rectilinear.
Epistemology	Knowledge is revealed by the power of nature through observations of consistent and richly interweaving patterns and by attending to nature's voices	Seeks knowledge as revealed by the power of reason applied to natural observations. (Pomeroy, 1992)
Reality of existence	Seeks to understand the reality of existence and harmony with the environment by turning inwards	Exploring only the outer world of physical existence. (Ermine, 1995)
Perspectives	Holistic perspectives with their gentle, accommodating, intuitive, and spiritual wisdom	Reductionist western science with its aggressive, manipulative, mechanistic, and analytic explanations (Allen, 1995; Ermine, 1995; Johnson, 1992; Knudtson and Suzuki, 1992; Peat, 1994; Pomeroy, 1992)
Empirical means	Celebrates the fact that the physical universe is mysterious but can be survived if one uses rational empirical means, albeit Aboriginal rationality and culture-laden observations (Pomeroy, 1992)	Guided by the fact the physical universe is knowable through rational empirical means, albeit western rationality and culture-laden observations (Ogawa, 1995)

It seems apparent from the studies discussed above that the worldviews of most indigenous societies are different from that of science and that this difference has an impact on the learning of school science. The influence of a society's worldview on the learning of science implies that curriculum planners, science educators, and researchers have to take it into consideration when planning instructional strategies. Swift (1992) suggested that a community could assist in making science relevant through the injection of indigenous knowledge, and by becoming a major instrument in education.

2.8.2 Worldview theory and science learners

Aikenhead (1996) has argued that to understand a learner's worldview is to anticipate which meanings in science curriculum will appear plausible and which will not. According to him, our perspective on how learners make sense of their natural world widens even further if we consider the worldviews that the learners possess. A number of studies (e.g., Ogunniyi 1987; Allen and Crawley, 1998; Lowe, 1995; Jegede and Okebukola, 1991a, 1991b; Kawagley, et al., 1988) have been conducted on students' views about diverse natural phenomena. Their underlying assumptions will be used as themes in the following discussion.

According to George (1999b), there is research evidence that the conceptions held by non-western learners prior to formal instruction may, in part, be a result of traditional practices and beliefs that exist in their communities and to which the learners are committed. When she investigated some of the traditional practices and beliefs operating in the daily lives of villagers in Seablast, there was some evidence that students and other individuals combined aspects of traditional system with aspects of science. More over, the outcome of the interviews with groups of high school students in the village indicated that there was some ambivalence on the part of the young people to the practices and beliefs of their forebears. She therefore concluded that the practices and beliefs of the students exerted some influence on their lives and how they understood the natural phenomena around them.

Lynch (1996b) performed a comparative study of primary students' understanding of the earth/sun/moon system in Tasmania (Australia) and the Philippines. Alternative frameworks elicited suggested that linguistic and cultural factors were in operation. The linguistic factors that influenced the students' conceptualisation were both lexical and semantic. In terms of cultural factors, the students explained the earth, moon and sun in terms of what they do instead of what they are. It was hypothesised that this was a reflection of a value system whish is more pragmatic in its priorities and that this influenced the learners' conceptions of the earth/sun/moon. In another study Lynch (1996a) discovered that the alternative conceptions of the students from Tasmania and the Philippines in relation to the nature of matter (solid, liquid and gaseous states) were once again linguistically and/or culturally determined.

Sutherland and Dennick (2002) explored the views of some First Nations (Cree) and Euro-Canadian Grade seven students in Manitoba had about the nature of science. They found that the two groups differed significantly on some of the tenets of the nature of scientific knowledge.

Lee, Fradd and Sutman (1995) described and compared science knowledge, science vocabulary, and cognitive strategies among four language and culture groups of elementary students. The findings revealed distinct patterns among the four groups. The findings also indicated relationships among science knowledge, science vocabulary, and cognitive strategies. This once again reflected the influence of the learners' worldviews on their conceptions of science knowledge.

Baker and Taylor (1995) have argued that although many of the learning difficulties of the non-western leaner have been highlighted in research studies, few attempts have been made to understand how a non-western learner might better learn science. Allen and Crawley (1998) compared the worldviews of Native American learners of the traditional Kickapoo Band with the worldviews encountered in the science classroom. They wanted to know if conflicts in their worldviews precipitated some of the problems they encountered in science. The underlying assumption of the study was that what the learners brought with them into the science classroom might have affected not only how they made sense of scientific information, but also the extent to which they were willing to participate in the educational experience. The subjects felt like outsiders in that the content, analogies, and pedagogy of the science classrooms had been foreign often conflicting with their worldviews. From their findings, Allen and Crawley (1998) concluded that the values that provided the foundation upon which educational decisions should have been contributed significantly to the conflict experienced by their subjects. In other words, the worldview differences which might have prevented the subjects from being successful in the typical science classroom were not such that could prevent them from participating fully in a scientific community.

In his study of the influence of preferred learning styles on cooperative learning in science Okebukola (1986) indicated that the cultural background of the learner could have a greater influence on education than does the subject content. This finding, according to Baker and Taylor (1995), was consistent with the research of Okebukola and Jegede (1990) that showed that reasoning based on a worldview that accepts the power of magic impairs a learner's of an empirical methodology and the acceptance of empirical evidence. The purpose of the Okebukola and Jegede's study had been to test the prediction that eco-cultural variables could exert influence in learners' concept attainment in science.

In a further study Jegede and Okebukola (1991a) investigated the supposition that observational skills can be influenced by learners' beliefs in traditional African cosmology, beliefs and superstitions. They suggested that the epistemology inherent in a learner's traditional worldview causes the learner to become involuntarily selective when making observations as well as to feelings of fear rather than to a body of conflicting knowledge. Locust's (1988) study had similar findings. He found that Native American students would choose to fail a biology class that requires dissection rather than suffer the consequences of bringing "bad luck" into their lives or the lives of their family members. These findings also supported earlier research by Ogunniyi (1987) on conceptions of traditional cosmological ideas among literate and non-literate Nigerians where he made the observation that superstitious reasoning is an impediment to concept learning and attainment in science.

The implication of the factors above is that a learner's cultural background tends to shape his/her worldview and the way he/she comprehends, manipulates or performs scientific tasks. As Okebukola and Jegede (1990) have argued, learners in a traditional society tend to explain naturally occurring phenomena in non-rational ways. The non-scientific explanations that learners within such communities normally use, very often, tend to exert significant influence on their cosmologies and scientific explanations presented to them in class. This is vividly illustrated by the case studies alluded to earlier (e.g. George 1999a and b; Aikenhead, 1997; Allen and Crowley, 1998). However, Thijs and Van Den Berg (1995) have argued that the performance of rural learners could also be due to lower quality of rural education and the authoritarian teaching styles of their teachers rather than traditional beliefs. They have also argued that

> The hindering effects of traditional beliefs on science understanding are not located in the contents of these beliefs as such….In other words, we do not believe that there is a serious interference between the contents of traditional/superstitious beliefs and scientific understanding, since the two domains are separated in terms of the types of questions considered (p.334)

Cobern (1993) has argued that cross-cultural studies have largely been based on western derived developmental theory. The underlying assumption and the ability being explored are at variance with those used in traditional societies. Cobern quotes Abiola as asserting that

> In many investigations, including those conducted by Africans, the imported research instruments…have been taken out of the conceptual context in which they were developed…If you use a culture-bound normative instrument, you end up with a better/worse comparison inference or "explanation": in most cases it is worse (Cobern, 1993: 297).

For example, Cobern argued that Okebukola and Jegede (1990) research subjects were deemed irrational because of low scores on a western-based measure of reasoning ability. For him, it was no surprise that the researchers found that the students showed illogical reasoning.

Several studies have shown that learners' traditional worldviews are not easy to replace with scientific worldview. For example, Lowe (1995) investigated the possible existence of an overall framework the learners in Solomon Island Secondary schools use to interpret the workings of the world and everyday life. He discovered that exposure to school science did not seem to bring about a radical change in the learners' worldviews. The study suggested that the science learners were able to retain much of their traditional worldviews while still appreciating the new view that science offered. They did this by being selective in what they accepted from science and when they could apply it. The learners slipped between two sets of worldviews comfortably. They had two sets of understanding about the nature of the world between which they could change when social circumstances demanded. Lowe (1995) has argued that this act of compartmentalizing the world into domains, each with its own appropriate interpretative framework, was not a perversity but an effective survival technique.

Cobern (1996b) has described the compartmentalisation of knowledge as a form of cognitive apartheid. He contends that learners simply wall off the concepts that do not fit their natural way of thinking. In such cases, he argues, the students create a compartment for scientific knowledge from which it can be retrieved on special occasions, such as school examinations, but in everyday life it has no effect. In another study, with college students, Cobern (1993) discovered that even though the students' ideas about nature were both rich and rational yet very little was about science. To him, "the most intriguing observation of the study was science's apparent lack of influence on students' beliefs about nature even though the students had been successful in college level science courses" (p.935).

Waldrip and Taylor (1999) studied the learners' perception of the prospects of science making a significant contribution to local cultural practices. They were concerned about the role of school science in shaping the future lives of peoples of non-western cultures. Their findings showed very little evidence of the positive influence of the school view of science on young people's traditional worldviews. They were left with the distinct impression that much of what went on in the high school science classroom in rural Kantri was of little relevance to the lives of most young Melanesians.

McKinley, McPherson-Waiti and Bell (1992) worked on an outline on language, culture and science education in New Zealand, with respect to the Maori people. They found that concern about the participation and achievement of Maori students in science education has led to considerations of their culture (beliefs, traditions, knowledge, heritage, experience and values) and the Maori language in science lessons. They also discovered that the Maori in favour of educating for bilingual students discarded a bicultural approach to science education.

Jegede and Okebukola (1991b) explored the effect of instruction on socio-cultural beliefs assumed to be hindering the learning of science. They attempted to see if instruction in selected science concepts through the use of the socio-cultural mode would have any effect on learners' attitude towards the learning of science. The results showed that instruction in science that is deliberately planned to involve discussions of socio-cultural views about science concepts engenders the students' positive attitudes towards the study of science. They argued that

> A parsimonious explanation for this finding could be that the teaching of science using the socio-cultural mode as filter serves to eliminate the apparent mismatch between the information and ideas brought into the science classroom from the traditional society and the scientific explanation of natural occurrence (Jegede and Okebukola, 1991b, p281)

An important implication of the findings is that science teachers and curriculum planners need to recognize the role that instruction through the socio-cultural mode could play in learners' development of positive attitudes towards the learning of science in traditional societies.

2.8.3 Worldview theory and science teachers

Ogunniyi et al (1995) have argued that what teachers hold to be true about natural phenomena is likely to condition learners' predisposition towards science. This is because science teachers, especially in non-western cultures, serve as a major source of information and this has made their students to have great confidence in them. They contend that teachers in non-western societies tend to command great respect among their students as people who know the secrets of the universe. Also, the teachers tend to maintain an authoritative posture over the students they teach with the result that their students tend to be generally passive recipients of knowledge. Thijs and Van Den Berg (1995) have argued that this pattern of behaviour on the part of teachers might be one of the causes for prevalent learners' alternative conceptions in non-western societies. This pattern of behaviour has been aptly demonstrated in the study carried out by Allen and Crawley (1998) on Kickapoo children who were found to be passive in class and to feel like outsiders. The study has also suggested that the way teachers understood the nature of science might have had a direct impact on the content and structure of the science classroom and on student learning.

With respect to science education, Ogunniyi et al (1995) have argued that the knowledge the teachers and students bring into class is critical in situating the teaching learning process within a meaningful context. According to Baker and Taylor (1995), this implies that science educators should understand the points of congruence and incongruence between traditional and scientific worldviews in order to teach a science that is relevant to the needs and culture of the learner. Some studies have been carried out on the teachers' worldviews and their influence on the teaching and learning environment. The rest of the subsection will devoted to some of them.

Contreras and Lee (1990) investigated the differential treatment of minority students by middle school teachers both in and out of classroom. Two aspects were stressed: (a) instructional content and teaching strategies and (b) citizenship policies in relation to outdoors science activities. This issue seemed particularly important, as such practices might deter minority students from gaining access to scientific knowledge and skills. The findings indicated that there were significant differences between the two teachers in the ways they treated their enriched and regular classes. One major implication that emanated from the study was that: when culture of the school or the teacher is not consistent with the cultural values of students, there is danger of cultural conflicts. In such a case, teaching may become a process in which the teacher imposes his/her own values and beliefs on the students, and the students resist learning that is imposed on them. The study then suggested teacher-training programmes that would help prospective teachers become aware of the cultural diversity of students. Further, that such programmes should provide teachers with tools and practices to deal with students from different cultural backgrounds.

Haidar (1999) examined Emirate pre-service and in-service teachers' views about the nature of science and found that the teachers' views were neither clearly traditional nor constructivist, that is, they held mixed views about the nature of science. The study concluded that using the constructivist view and Jegede's (1995) collateral learning in introducing science would help to diminish "symbolic violence".

A powerful tool for understanding the conflicts in cross-cultural teaching as Allen and Crawley (1998) have found, based on their Kickapoo study, is the worldview theoretical model. They have suggested that, by examining the ways in which scientific ways of thinking are integrated into other beliefs, science educators might more successfully separate ways of thinking and acting which could be essential to the nature and practice of science from those which are cultural artefacts which might hinder science learning. In this regard, George (1999b) has pointed out the need for science teachers to understand the worldviews supporting learners' ideas about various natural phenomena before introducing them to the scientific worldview of such phenomena.

Ogunniyi et al. (1995) have argued that science teachers have a key role to play in science teaching. Teachers could determine the success of a curriculum by consciously or unconsciously shaping the nature of the information conveyed to students. Also according to Ogunniyi and Yandila (1994), education in science does not guarantee that the science teachers would transmit valid views about science to their students or that they would point out the limitations of alternative conceptions held by their students. As Ogunniyi et al (1995) have also argued, it is possible for science teachers to convey a distorted image of science through a mechanistic worldview while holding worldviews that depend on their cultural backgrounds. They carried out a study to identify the nature of the worldview presuppositions held by a group of science teachers from five non-western cultures, namely, Botswana, Indonesia, Japan, Nigeria and the Philippines. One of the findings in that study is that the science teachers held views distinct from the science they teach.

Bandiera, Neves and Vicentini (1999) also carried out a similar study to investigate using a modified version of the instrument used by Ogunniyi et al. (1995), if Italian science teachers held views a multiplicity of worldview identical to those by Brazilian science teachers. Their findings showed that Italian and Brazilian teachers held worldviews that coexisted with the scientific one. They also found that more Italians teachers tended to accept scientific statements and to reject statements relating to magic-mystery, religion and spiritism, and parapsychology more than their Brazilian counterparts.

In another study, Haidar (1997) explored the nature of Arab prospective teachers' worldview presuppositions towards nature. The worldview presuppositions, in a bipolar form, were: safety and fear; order and chaos; aesthetic and materialistic; special and mundane. The results showed that the teachers' presuppositions were mostly religious. The study concluded that science education programmes in the Arab culture should be made culturally sensitive.

Jegede (1995) has argued that the way school science is currently taught projects only one worldview: the western view. He contends that the western view holds claim to superiority over any other means of studying nature. He argues further that the western view neither recognizes the variation among people nor the different worldviews that learners bring into the science classrooms. He has, therefore, suggested that rather than convert students so that they shed their indigenous primitive worldview in favour of more scientific explanations, school science should recognize the situations in which these presumably non-scientific are useful and to them in contexts other than the science classroom.

Haidar (2002) investigated the perspectives of Emirate secondary school science teachers on the nexus between modern science and Arab culture. The results indicated that these teachers did not view modern science as a sub-culture of the Western culture, and that they found no differences between modern science and Arab culture.

Proper, Wideen and Ivany (1988) tried to identify the worldviews projected in teacher talk. They found that only a limited set of worldviews was projected in the science dialogues. Further, they discovered that the type of worldview presented by the teacher in class was instrumental in shaping the learners' worldviews and by projecting a fairly broad range of worldviews; teachers could make their learners more aware of alternative worldviews and meanings capable of stimulating their scientific thinking. They contended that if the scientific worldview were projected openly or overtly, the learners would be able to appreciate the veracity of that worldview. On the other hand, if a narrow worldview was projected in a hidden manner or covert manner the inherent meanings might be hidden from the learners as it might fail to stimulate their intellectual interest.

Lawrenz and Gray (1995) explored the relationship existing between prospective teachers' characteristics and worldviews, and their understanding. They found that the subjects' home location and characteristics had a fairly strong relationship on their worldviews.

From the foregoing discussion, it is evident that science teachers need to recognize that learners' disposition to the learning of school science concepts can be greatly influenced by eco-cultural factors (Okebukola and Jegede, 1990). They need to understand the fundamental, culturally based beliefs about the world and how these beliefs are supported because science education is successful only to the extent that science can find a niche in cognitive and cultural milieu of learners. What is more, the learning environment would be improved if the teachers were more aware of learners' worldviews as related to science. Those who teach science should create a learning environment that provides intellectual freedom where the learners are respected as thinking individuals capable of expressing their own views. They should encourage learners to talk about how what they learn from science compares with what they believe the world to be like (Cobern, 1993). These discussions should lead to a consensus on the terms and concepts used to explain phenomena and should include considerations of worldview cultural perspectives and other more metaphysical concepts (Lawrenz and Gray, 1995). This would illuminate and bring to consciousness in the learner the meaning and values of his/her experience with natural phenomena (Ogunniyi et al. 1995; George, 1999b; Jegede and Okebukola, 1991a and b). However, there is a need to equip teachers through pre-service or in-service training where the teachers will be taught the various ways of incorporating the cultural backgrounds and worldviews of the learners in their teaching strategies. This would also necessitate a training program that includes the philosophy of science.

2.8.4 Worldview Theory and Curriculum Material

As alluded to earlier, George (1999b) observed that an approach which views science as the process of crossing the boundaries between the subculture of a student and the subculture of science would necessitate the need to provide some learning aids to facilitate that process. However, to be effective, such learning aids should be simple, relevant to context and match the development of the students. If they were not, science instruction would not be effective. For example, in the Yupiaq case studied by Kawagley et al. (1998) referred to earlier, the science curricula and the textbooks based on them assumed that grasshoppers, cows and sidewalks were a part of every child's daily life when in actual fact none of the Alaskan children had seen any of these. Several studies have been carried out to investigate the resources, textbooks and types of curricula used in so-called indigenous societies. Some of these studies are discussed below.

George (1992) explored the use of Caribbean indigenous resources in the teaching of science. This was action research aimed at: (a) sensitising teachers to the possible uses of Caribbean indigenous resources in the teaching of science, and (b) developing a preliminary model for the incorporation of indigenous resources in science curricula. The teacher assessment of the instructional possibilities of the prototype, and reflections on subsequent efforts to incorporate indigenous resources in their teaching, indicated that this innovation was viable with potential benefits for the students but that support systems need to be put in place, especially for inexperienced teachers.

Matthew and Smith (1994) investigated the effects of using culturally relative materials with Native American students. They argued that the low achievement of Native American learners, as measured by standardized tests, results from a number of factors, including the lack of cultural relevance of curriculum materials used in their instruction. Using pre-test post-test control groups design, Grades 4 to 8 Native American learners in Bureau of Indian Affairs schools (who were taught science using culturally relevant materials) performed significantly higher than their counterparts who were taught science without the culturally relevant materials. Matthew and Smith then made the suggestion that educators of Native American should use materials that incorporate frequent reference to Native Americans and science when they teach science.

Ogawa's (1989) inspection of Japanese school science programmes revealed that while the elementary programme was well received by Japanese learners, the secondary one was not. He attributed this to the nature of Japanese culture, which has the love of nature as one of its presuppositions. He indicated that the elementary school science programme succeeded because it was based on this presupposition while, on the other hand, the secondary school science programme failed because it was not. The latter was westernised.

Barba (1993) conducted a needs assessment of bilingual/bicultural elementary science classrooms in order to determine in the current instructional environment addressed the educational needs of Hispanic/Latino children. The findings indicated that the children were receiving science instruction: (a) with culturally asymptotic printed materials, teaching strategies, and supplementary materials; (b) in classrooms that did not use the children's native language, *familia* learning groups, peer tutoring, or manipulative materials, and (c) with oral and verbal and verbal instructions that lack culturally syntotic role models, examples, analogies, and elaborations. Findings from this study imply that changes are needed in pre-service and in-service teacher training, in science textbook formats, and in the scope and focus of elementary school bilingual/bicultural science curriculum and instructional strategies.

In another study that compared the worldview of Native American students of the traditional Kickapoo Band with the worldview encountered in the science classrooms, Allen and Crawley (1998), recommended that textbooks authors, teachers and reviewers ought to be sensitive to expressions of worldview and avoid those which are blatant cultural biases or those that are inconsistent with current theories of the nature of science. It is their view that textbooks are likely to make learners feel like outsiders as was in the case of the Kickapoo children involved in their study. A probable reason for the feeling of foreignness experienced by students according to Apple, is that textbooks:

> Signify - through their content *and* form- particular ways of selecting and organizing that vast universe of knowledge. They embody…[a] *selective tradition-* someone's selection, someone's vision of legitimate knowledge and culture, one that in the process of enfranchising one group's capital disenfranchises another's. (Cobern, 1993:299)

Ninnes (2000) used a discourse analysis technique to examine the incorporation of indigenous knowledge into textbooks. He looked at two sets of junior science textbooks published and used in Australia and Canada. He chose the two countries because they were comparable since both had indigenous people and were both former British colonies. His findings showed that both textbook sets had provided extensive representations of indigenous knowledge. The knowledge could be categorized as relating to myths and legends, indigenous technology, indigenous knowledge of the natural world, indigenous social life and so forth. However, he sounded a few warnings especially in situations where multicultural science classrooms were prevalent. Firstly, he contended that attempts to include indigenous knowledge could be counter-productive by reproducing racist stereotypes. Secondly, that representations of particular indigenous lifestyles as traditional, needed to be reconsidered, particularly the implication of authenticity which such a term conveys, and the concomitant implication of lack of authenticity which is thereby attached to other indigenous lifestyles. Thirdly, that textbook authors and curriculum developers needed to take more care to establish which indigenous practices and beliefs were extant in order to avoid giving the impression, through the use of past tense, that certain practices and beliefs belonged only to antiquity. Finally, he pointed out the need to understand the role played by the indigenous peoples in the whole process. This would involve the extent to which the incorporation of indigenous knowledge had occurred through processes of consultations and partnerships with indigenous peoples and therefore, the process the extent to which the process had empowered and enfranchised the indigenous peoples.

Some of the studies concerned with the socio-cultural context of learners have recommended that curriculum developers should pitch curricular material within the framework of the socio-cultural backgrounds of the learners. That is, the daily occurrences in the learners' immediate environment should be related to the learning experiences in science provided him/her under the auspices of the school (Okebukola and Jegede, 1990; Jegede and Okebukola, 1991a and b). This would require the infusion of indigenous knowledge and worldview into the curriculum as well as modelling the science curriculum through indigenous thought systems (Kawagley et al., 1998). Regarding curriculum packages that utilize the African view of nature, Jegede and Okebukola (1991a) have recommended that that they need to base their objectives on: (1) Generating information about the African environment to explain natural phenomena; (2) Identification and use of fundamental scientific technological principles, theories and concepts of indigenous practices within the African society; and (3) The teaching of the values of the typical African humane feelings in relation to, and in the practice of technology as a human enterprise. However, all of the above recommendations would require a curriculum perspective that views science education as the process of border crossing (George, 1999a). There would also be a need to train the curriculum developers in terms of culture and worldview.

2.9 SITUATING THE STUDY.

As Cobern (1996a) has noted there is a need for science educators to seek a better, and a more inclusive concept of integrating distinct worldviews in the teaching-learning process in terms of scope and force on learners, particularly the way in which this could be related to their scientific study of nature. Baker and Taylor (1995) have observed that little research addressing the development of science understanding in children has been focused on non-western learners. To them, very few attempts have been made to understand how a non-western learner might better learn science. This has been specially the case in Africa where, according to Jegede (1995), the literature is very sparse on information processing and where collateral learning or duality of conceptions is prevalent.

Aikenhead and Jegede (1999) have proposed what they call intellectual tools for understanding what goes on in the minds and hearts of learners when they learn science. They seem to construe the Collateral Learning Theory (Jegede, 1995) as the cognitive explanation of border crossing. However, their cognitive explanation is not specifically designed for the African learner and as such does not explain what goes on in the mind of the African child as he/she learns science. Adams (1999) has argued that, attractive as the Collateral Learning Theory has been in explaining border crossing, it has fallen short of explaining how the two worldviews are linked. On the other hand, Ogunniyi (1995, 2002a and b) has posited the Contiguity Learning Hypothesis as a possible explanation of the mechanism of cognitive border crossing. Adam (1999) has suggested the need for a more collaboration to find ways whereby the Collateral Learning Theory and Contiguity Learning Hypothesis could provide a clearer understanding of the phenomenon of border crossing. It is against this background that this study has attempted to suggest a plausible model and known as "The African Learner Model" that which has combined Aikenhead's cultural border crossing, Jegede's Collateral Learning Theory and Ogunniyi's Learning Hypothesis to explaining **how** an African learner acquires or rejects the scientific concepts presented in his/her science classroom. Details of the model will be discussed in Chapter five.

2.10 CONCLUSION

The review carried out in this chapter has explored various explanatory models based on the constructivist view of learning school science in a non-western classroom. The tenet of constructivism is that learners do not enter classroom with blank minds, but hold certain pre-conceptions or alternative worldviews, acquired from their socio-cultural environment. Most of the studies reviewed indicate that the traditional worldviews held by learners very often act as barriers to the study of science. However, it is not clear how these studies have reached the conclusion that such worldviews necessarily hamper learners from studying science. No doubt, constructivist – based research has consistently shown that learners hold a multiplicity of worldviews and such worldviews could create conflicts in the minds of learners when exposed to school science. But as Jenkins (2000) has noted that the use of intuitive commonsensical notions or the so-called alternative worldviews may be purely instrumental in coping with experience rather than act as barriers to study of science. Both Jenkins (2000) and Phillips (1995) have shown the merits and demerits of constructivism. They have commended the constructivists for bringing to the fore epistemological issues in the discussion of learning and the curriculum and their emphasis on a learner-centred instruction, but have criticized the lack of guidance provided for the implementation of recommendations ensuing from these issues.

Next the review examined a number of theories/hypotheses that have been proposed to explain the phenomena of border-crossing viz: the Border Crossing Theory, Collateral Learning Theory and the Contiguity Learning Hypothesis. This was followed by examples of studies that were carried out on the worldview presuppositions held by students, teachers and indigenous people in non-western societies and how these might affect the teaching and learning of science. These studies have suggested some valuable recommendations and crucial implications for science education. They have recommended that the science curriculum be embedded with indigenous knowledge, and that teachers be trained in order to create a learning environment that encourages active participation on the part of learners. However, as some science educators (e.g. Jenkins, 2000; Ogunniyi, 1996) have already pointed out, this is not as easy as it sounds

It is in the light of the above views and arguments that this study hopes to investigate the nature of the subjects' worldviews and the types of border crossings they underwent when they moved from their alternative worldviews to the science worldview on some natural phenomena. The next chapter provides some details of the procedures followed in developing valid and reliable instruments, and a full description of details of the research methodologies used to investigate the nature of the learners' worldviews as well as the types of border crossings they experienced during an intervention.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This study was concerned with examining the type of worldviews held by Swazi high school learners on the one hand and the effects of a culturally sensitive teaching/learning method on the other. To achieve this aim the investigator followed a carefully laid down procedure, which included such things as:

- Setting a number of criteria for sample selection and scope of the study
- Selecting research designs
- Developing a number of instruments
- Data collecting and analysis
- Selecting the concepts to be focussed on
- Developing the exemplary materials

Details of these procedures are presented in the sections that follow.

3.2 SAMPLE SELECTION AND SCOPE OF STUDY

A total of 128 fourth year senior secondary school learners enrolled in the Cambridge Ordinary Level Physical Science Syllabus were used as subjects of the study. Their ages ranged from below 16 years to above 23 years. The subjects were assigned to three groups: the experimental group (E), the true control group (C_1), and the group controlling for the pre-test effect (C_2). The three groups were three intact classes from three different high schools that were selected because:

- Of distance convenience since the researcher had to teach in E_1 and C_2 simultaneously.

- They were all situated in same rural region, which meant that the subjects were likely to have been exposed to similar socio-economic conditions, and were probably familiar with the traditional practices found in that particular socio-cultural environment.
- The schools' past Cambridge Ordinary Level results were more or less similar.
- They followed the same Cambridge Ordinary Level syllabus. (The Cambridge Ordinary Level offers a variety of science syllabi which vary from school to school)

The experimental group (E) consisted of 51 learners of this 27 were males and 24 females. Of the 46 learners in the true control group (C_1) 21 were males and 25 females. The second control (C_2) had 31 learners of which 19 were males and 12 females. It must be explained here that the researcher could not get a school with a bigger enrolment of learners for a second control because Swaziland is very small and has few schools within the same radius, especially in the rural region where the study was carried out.

3.3 SELECTING RESEARCH DESIGNS

The study used both an experimental and a qualitative research designs. These are described in the following sub-sections.

3.3.1 The Experimental Research Design.

Experimental research was used for this study because was found appropriate "in describing the consequences of a direct intervention into the status quo" (Ogunniyi, 1992: 81). The researcher in this case purposely manipulated and/or controlled certain conditions that determined the outcomes she had interest in. A quasi-experimental design was then chosen for the study. This kind of design is one that does not expose the subjects of the experimental and control groups through a randomisation process like in a true experiment resulting in the groups being non-equivalent, and constituting intact groups such as schools or classrooms (Cohen, Manion and Morrison, 2000; Schumacher and McMillan, 1993; Ogunniyi, 1992). Such a design can also be referred to as a "Non-equivalent Pre-test-Post test Control Group Design" (Schumacher and McMillan, 1993). It involves three groups with two groups being administered the pre-test and one not. One pre-tested group and another that was not are normally exposed to the experimental treatment. The three are then all post-tested after the completion of the experimental treatment. This design can be illustrated as follows:

O_1	X	O_2	(E)
O_3		O_4	(C_1)
	X	O_5	(C_2)

X = treatment; O = observations; E = Experimental group; C_1 = Control group 1; C_2 = Control group 2.

Fig. 2: Research Design used for the study

The dashed line separating the parallel rows in the diagram of the non-equivalent groups indicates that the experimental and control groups have not been equated by randomisation – hence the term "non-equivalent" (Cohen, Manion and Morrison, 2000). One advantage of this design is that it has some control over internal validity threats such as subject characteristics, mortality, instrument decay, testing, maturation, history, and regression. However, it is a disadvantage in a sense that it has a weak control over internal validity threats such as attitudinal threats, implementation and location (Ogunniyi, 1992; Schumacher and McMillan, 1993).

For the present study the three groups were three intact classes from three different high schools, and as such, did not require a random assignment of the subjects. Both the experimental group (E) and the first control group (C_1) wrote a pre-test and a post-test. The second control group (C_2) only wrote a post-test. The treatment consisting of concept mapping and socio-cultural instructional strategy (see section 3.7) was applied to E and C_2, and was taught by the researcher. This was to ensure researcher control over the experimental treatment (Fraenkel and Wallen, 1993; Tuckman, 1978). Fraenkel and Wallen (1993) argue that it is an essential requirement for a well-conducted experiment to have the researcher have control over the treatment, that is, to control the what, who, when, and how of it. They further argue that the greatest control is likely to occur when the researcher is the one implementing the treatment or intervention even though this provides the greatest source of "implementer threat". The class teacher taught the first control group (C_1) using the normal or usual way, which was provided as a placebo to the exemplary teaching strategy, that is, C_1 controlled the method of instruction and learning. The group's performance was compared with that of the experimental group to investigate the effect of the treatment. C_2 controlled the effect of the pre-test on the learners' performance. The research instruments used for this design were in the form of questionnaires and tests, which will be discussed in section 3.4.

3.3.2 The Qualitative Research Design

To obtain a more holistic impression of the teaching and learning that took place in the three classrooms, the researcher included a case study to provide qualitative data in terms of: (1) determining the nature of border crossing that might have occurred, and (2) analysing how it could have taken place within the classrooms of the groups that underwent treatment. It was hoped that this approach would reveal whether or not any border crossing actually occurred as a result of the treatment specifically designed to bring about conceptual change among the learners. The learners' narrations of their feeling, beliefs, ideals, thoughts and actions (Schumacher and McMillan, 1993) were used in this regard.

3.4 DEVELOPING RESEARCH INSTRUMENTS.

The three research instruments used for data collection consisted of the questionnaire, "My Idea About Nature" (MIAN); the Physics Achievement Test (PAT); and the videotape. The details of each instrument are provided in the sub-sections that follow.

3.4.1 The My Ideas About Nature (MIAN) Questionnaire

This questionnaire, "My Idea About Nature" (MIAN) used in this study was a modified version of the MIAN developed by Ogunniyi (1999). The MIAN was used to determine the scientific and technological literacy of primary and secondary school learners in South Africa. The MIAN was modified from a previous instrument known as the "Traditional Cosmological Test" (TCT) tested in five non-western countries and had reliability values ranging between 0.85 and 0.95 using Kuder-Richardson-21 (Ogunniyi, 1987; Ogunniyi et al., 1995). The modified MIAN had a reliability value of 0.80.

The MIAN consisted of two parts. Part A was the subjects' demographic information and Part B was made up of eight fictitious stories about selected natural phenomena, to which all the three groups had to express their agreement, disagreement or uncertainty with respect to five plausible explanations below each story. For triangulation purposes, open-ended questions were included where each subject was expected to write his/her own opinion about the phenomenon described in that particular story. For the purposes of this study, only the first and fifth stories were adjusted in terms of cultural relevance to suit a Swazi child living in a rural socio-cultural environment. The MIAN was pilot tested using a Grade 11 class from a school situated in the same socio-cultural environment, and which used the same Ordinary Level Cambridge Syllabus as the three that were later used in the study. The class consisted of twelve learners out of which six were males and six females. Their ages ranged from seventeen years to above eighteen years. Ten of them indicated a high interest in science while the other two a low interest. The responses from the pilot test resulted in changing the wording in some of the items to make them more understandable and less ambiguous. The section on the questionnaire where the learners had to indicate their age was also adjusted to include a wider and more specific scale. For example, instead of reading: 17, 18, and >18 years old, it changed to: <17, 17, 18, 19, and >19years old.

Part A, the subjects' demographic information, was used for answering the third research question, which was about the possible influence of demographic factors on the subjects' responses. Part B was used for answering the first research question on the identification of the subjects' worldviews on certain conceptions about natural phenomena. For the purposes of analysis, the items under the eight fictitious stories were grouped into five major themes or categories. Each of the five response choices or options under each story was assigned a number, which resulted in a total of forty items. The grouping was to reduce the possible influence of under- or overrepresentation of certain presuppositions (Ogunniyi et al 1995). The categories were: Magic and Mysticism (items 4,7,9,10,15 and 38); Metaphysics, Parapsychology and Pseudo-science (items 11, 12, 14, 16, 26, 27, 28, 29, 32, 35, 36, 37, 39 and 40); Spiritism (items 1, 3, 5, 18, 19, 20, 21, 22, 23, 24, 30, and 33); Rationalism (2, 6,13, 25) and Science (8,17, 31, and 34). These categories were validated by a group of five science educators. These experts were asked to rate the items on a scale of 1 to 5 to express their agreement or otherwise on the category of each item. The reliability coefficient was calculated as 0.80 using Spearman Rank Difference Correlation.

3.4.2 The Physics Achievement Test (PAT)

The Physics Achievement Test (PAT) was used to obtain pre-test scores for schools E and C_1 and post-test scores for E, C_1 and C_2. It is a criterion-referenced test in that it was constructed to measure a set of operationally or behaviourally stated objectives (Tuckman, 1978) on the topics of Force, Energy, Work and Power found in the Cambridge Ordinary Level syllabus for Physical Science. The ten objectives were to:

- Describe the moment of a force in terms of its turning effect and give everyday examples
- Make calculations involving the principles of a force
- Use the relation between force, mass and acceleration
- Demonstrate an understanding of the effects of friction on the motion of a

body

- Describe, and express a qualitative understanding of, processes by which energy is converted from one form to another
- Use the terms kinetic energy and potential energy in context
- Calculate kinetic and potential energy in context
- Show qualitative understanding of efficiency
- Relate work done to the magnitude of a force and the distance moved
- Relate power to energy transferred and time taken

Questions were extracted from several textbooks (e.g. Byron, 1992; Avison, 1989; Heuvelen, 1982) that had used past examination papers from examination boards such as: the Joint Matriculation Board (JMB), the Associated Examination Board (AEB), the Oxford and Cambridge School Examination Board (O&C), the Oxford Delegacy of Local Examinations, and the University of Cambridge Local Examination Syndicate. The questions were then modified by: contextualizing them; embedding them within stories, anecdotes, and life histories of Swazi people; and situating them in the beliefs and values of the Swazis. For example, a question reading " A machine is a device that changes the size of a force and enables work to be done more easily. State why it can never be a 100% efficient", would read as follows:

> Babe Dlamini works for Shiselweni Forestry. His job is to cut down trees using an electric saw (ihhomulayini). One day his foreman (indvuna) was heard complaining that Babe Dlamini was slow. Babe Dlamini defended himself by explaining to the foreman that his saw was no longer a 100% efficient. Explain what Babe Dlamini meant by this.

Two types of validity were applied on PAT: construct validity and content validity. For Construct Validity: PAT represented a sample of actual performances (Tuckman,

1978) and measured the learners' achievements of the objectives, conceptions, process skills and applications (Klausmeier, 1980). According to Tuckman (1978), construct validity relates a presumed measure of construct or hypothetical quantity with some behaviour or manifestation that is hypothesized to underlie (or, conversely relating a behaviour to a test of some construct that is an attempt to explain it. These measures of traits or abilities (Dembo, 1982) were represented in the form of categories of scientific performances, which were structured to be in line with some of the assessment framework used in the Science and Technology Literacy (STL) project (Ogunniyi, 1999). These are:

- The use of process skills to investigate
    - Use of graphical and symbolic representation
    - Accurate reading and/or estimation of common measurements
    - Planning scientific investigations
- The conceptions of scientific concepts and principles related to Force, Energy, Work and Power.
- The innovative application of scientific knowledge and skills.
- Scientific versus alternative conceptions or traditional worldviews.

For Content Validity: PAT represented an attempt to maximize content validity or appropriateness based on the set of objectives outlined in section 3.4.2 above. It aimed for an adequate sampling of the specified topics on Force, Energy, Work and Power under the Physical Science Syllabus. PAT was considered to have content validity because, according to Tuckman's (1978) definition of such a test, it measured a sample of situations or performances that were representative of the set from which the sample was drawn, and about which generalizations were to be made. The instrument was pilot tested in the same group of Grade 11 learners from a school situated in the same socio-cultural environment as the three that were later used in the study who wrote the MIAN pilot test. Their scores were used to calculate the test's reliability. The reliability was found to be 0.98 using the Kuder-Richardson (KR_{21}) correlation coefficient, and 0.92 using Spearman Rank Difference Coefficient.

3.4.3 The Videotape Recorder

This study also included videotape recordings. Schumacher and McMillan (1993) assert that observational procedures can record naturally occurring behaviour and avoid some of the disadvantages associated with questionnaires and interviews. The major advantages of videotape recorders are:

- The provision of a comprehensive record of classroom behaviour that can be preserved for subsequent analysis
- The fact that the cameras deal with conventional classroom settings (i.e. the fidelity of the system is good), and microphones are able to pick up the greater proportions of the public utterances that take place.
- The stop-rewind facility of the VCR permits sequences of behaviour to be viewed and reviewed at will during data coding. (Cohen and Manion, 1980)

The videotape recorder was used in this study to record a discussion on the learners' views concerning two phenomena found in their socio-cultural environment based on two of the questions in the PAT. A group of twenty subjects from groups E and C_2 were asked at the end of the instructional intervention, to debate amongst themselves their views on certain phenomena and their discussions were recorded in a video since all of them came from the same traditional society and most probably subscribed to the prevailing traditional cosmological ideas in their indigenous community. The assumption however, was to be confirmed at the video recording sessions. It was also hoped that any change in the worldviews of the subjects would be confirmed during the same sessions. To facilitate the process a number of questions were posed to the subjects and their responses were then videotaped. The assumption was that any change in their viewpoint would be picked up from the ensuing discussion. But before asking the questions two stories based on prevalent traditional beliefs were narrated to the subjects by the researcher (see Appendix 3). This approach is in line with Cobern's (1996b) argument that

> Sharing beliefs openly upon beginning study of a controversial topic and sustained, small group, student-led discussions that encourage and practiced could bring beliefs to the surface to be examined not by an authoritative figure, but by a colleague- collaborator- and finally by the believer herself.... What is required is that a teacher think about worldview questions and how students might answer these questions differently from the way they are explicitly or implicitly answered in the science curriculum (p.604).

3.5 DATA COLLECTION AND ANALYSIS

The researcher used the head of the science department in one of the three schools as a coordinator. His duty was to negotiate with the other schools to delay the teaching of the topic of force, energy, work and energy so that the researcher would teach these during the data collection period.

3.5.1 Data Collection using the MIAN questionnaire

At the beginning of the data collection period, the researcher visited all three schools to explain the purpose of the study and to familiarize her with the learners that were to be used as subjects for the study. During the first visit the researcher met with the class teachers and head teachers. She also collected timetables for the science periods and negotiated for changes where there were clashes. The second visit was used for administering the MIAN. The three groups wrote the questionnaire during one of their science periods. The subjects were asked to fill in the details indicating their sex, age and interest in science. They were also encouraged to write their authentic views since their responses would be anonymous in the sense that they would not write their full names but would instead use their initials. The initials were required so as to enable the researcher to trace a particular student's responses in the various instruments during data analysis.

3.5.2 Data collection using the Physics Achievement Test (PAT)

The third visit to the experimental group (E) and the first control group (C_1) was used for administering the pre-test. This was done during one of the science periods. The subsequent visits to E and the second control group (C_2) were part of the intervention where the researcher taught the two groups for a period of six weeks (see details in the following subsections). The researcher chose the role of participant-as-observer for this study because of her role as the teacher of the experimental group (E), and the second control group (C_2.). According to Fraenkel and Wallen (1993), a participant-as-observer is a person who has revealed his/her role as researcher to the school authorities before assuming his involvement as participant in the activities of a group, in this case teaching in the classrooms under study. The post-test was administered during the last period of the six weeks in each of the three groups.

3.5.3 Data collection using the videotape recorder

The researcher made arrangements with a local teacher training college to have one of the student teachers to assist her in videotaping the discussions of two groups each consisting of ten learners from both groups E and C_2. As already mentioned, the discussions were based on two stories that were similar to two of the questions in PAT, and were aimed at testing whether or not border crossing from a traditional worldview to a scientific worldview had taken place in the subjects after the treatment. Even though the videotape pictures were not clear because of insufficient lighting, the research was able to capture all the crucial points, which were later used in the analysis described in chapter four.

3.5.4 Data analysis

For the purposes of analysing the data collected from MIAN, a percentage frequency was given for each response under each story and the subjects' responses to the open ended questions were categorized according to five themes: magic and mysticism; metaphysics, parapsychology and pseudo-science; spiritism; rational; and science. Conclusions were then made to decide on the types of worldviews held by the learners as required by the first research question.

Data obtained through the PAT were analysed in terms of: (a) the mean scores, standard deviations, zero percentages, valid scores and maximum scores for each question; (b) excerpts derived from the subjects' opinions or viewpoints; and (c) demographic features such as gender, age and interest in science. The conclusions drawn were then used for answering the second and third research questions. The second question was concerned with determining the difference between the scientific and traditional views of learners who had been exposed to different teaching and learning strategies while the third question was to find out if certain demographic factors influenced the subjects' traditional and scientific worldviews. The subjects' videotape discussions were analysed in line with the theories/hypotheses of border crossing, collateral learning and contiguity learning.

3.6 DEVELOPING EXEMPLARY TEACHING STRATEGIES

The exemplary instructional/learning materials designed for use in groups E and C_2 consisted of three modules. Each module was divided into lesson plans and/or practical activities. The Cambridge Ordinary Level instructional objectives for the topics on Force, Energy, Work, and Power were divided into three modules as shown in Fig. 3 below. Each module had several instructional objectives, which were used

Module I Forces
1. Effect on shape
2. Effect on motion
3. Turning Effect

Module II Energy
1. Forms of energy, its conversion and conservation
2. Major sources of energy
3. Efficiency

Module III Work and Power
1. Work
2. Power

Fig. 3: Modules Used During The Intervention

to plan each lesson. Each lesson was then taught using a socio-cultural teaching model including concept mapping designed for the purpose. These two strategies are discussed in the following sub-sections. Even though Group C_1 covered the same topics as the other two groups, it was taught the regular way by the class teacher.

3.6.1 Concept Mapping

The Experimental group (E) and the second control group (C_2) were introduced to concept mapping at the beginning of the treatment. Concept mapping is a heuristic device invented by Novak (1990). It is based on Ausubel's theory of meaningful learning that stresses the importance of prior learning in the acquisition of new concepts. According to Ebenezer and Connor (1998), Novak had elaborated on Ausubel's ideas, arguing that the quantity and quality of relevant concepts and prepositional frameworks are primary factors in new learning. From a constructivist viewpoint, meaningful learning requires the learner to connect newly introduced concepts to their prior knowledge. Unlike rote learning, which involves largely memorizing facts and concepts; meaningful learning through the use of concept maps involves understanding and integrating new knowledge into one's cognitive structure. In other words, concept mapping helps learners to not only understand what the concepts they learn are and to relate them to others, but to also relate them with information already in the long-term memory (Eggen and Kauchak, 1994).

Concept maps are made of concepts and linking words or prepositions. They are defined by prime descriptors (key words or components), representing selected key concepts, which are then linked by propositions (statements) that explain the links being made between the prime descriptors. An arrow showing the direction of the linking statement is then drawn between the concepts (Adamczyk, Willson and Williams, 1994; Heinz-fry and Novak, 1990).

Concept mapping was chosen for this particular study because it was found useful in, among other things, facilitating meaningful learning in that it enhances integration and retention of knowledge by increasing the number of relevant concepts that can be connected to new material (Heinze-Fry and Novak, 1990). It was used to help the subjects to learn meaningfully so that they could make meaningful links between the science concepts taught in class and some everyday life phenomena found in their socio-cultural environment. Novak and Gowin (1984) argue that concept mapping as a learning tool, allows the learner to understand the relationship between ideas by creating a visual map of the connections that will allow him/her to: (a) consider the relations between ideas which he/she already knows; (b) connect new ideas to knowledge that he/she already knows; and (c) synthesize new ideas in logical order that allows future information to be involved. According to Lambiote and Daisereau (as cited by Dinie, 2000), the concept would thus allow the learner to have a broader knowledge base that will enable him/her to solve problems better than a learner who practices rote learning.

Due to some time constraint, the concept mapping strategy was used in only three fifty-minute lessons: two at the beginning and one towards the end of a six-week period. The researcher had limited time for completing all the topics because of interruptions in the form of choir practices and soccer tournaments in which the schools were involved. The first lesson was devoted to training the subjects on the construction of concept maps. The researcher used the general topic of "Taxis" to illustrate how the different concepts such as taxi fares, speed, distance, destination, capacity, music (sound), and so forth, could be linked together to construct a concept blank mind, but holds certain pre-conceptions and/or alternative worldviews, which he/she has acquired from his/her socio-cultural environment, and which might in fact prevent him/her from developing a valid scientific worldview. The socio-constructivists argue that science education should start from the learners' understanding of natural phenomena (Cobern, 1996a; Lawrenz and Gray, 1995; Jegede, 1995; Jegede and Okebukola, 1991b; Hacking and Garnett, 1985). According to these social constructivists, recognizing the learners' prior knowledge helps the teacher to understand why he/she cannot assume that his/her explanations and/or demonstrations will be interpreted by the learners in ways which he/she had intended (Taylor, 1997).

Furthermore, Jegede and Okebukola (1991a) assert that teachers should become more aware of the impact of cultural variables as traditional beliefs and religious affiliations in their teaching efforts. They argue that instructional strategies should meet the cultural background learners bring into the science classroom. Also Jegede and Okebukola (1991b) argue that the teaching of science using the socio-cultural mode as filter serves to eliminate the apparent mismatch between the information and ideas brought into the science classroom from the traditional society and the scientific explanation of natural occurrences. The prime aim of the suggested strategies is to provide a teaching/learning situation in science that makes it possible for learners in traditional settings to have easier access to science through overt comparisons of their worldviews and that of science, so that they would be in a better position to evaluate the likely contradiction of science to their lives (George, 1999b). Thus, the central concern of this study was to use an exemplary culturally sensitive instructional strategy that could help the learners to bridge the gap between their worldviews and the scientific valid view of force, energy, work and power.

Each lesson was made culturally relevant by employing Manzini's (2000) method based on Jegede's (1995) eco-cultural paradigm proposed to enable learners from non-Western cultures to cross the borders between their traditional worldviews found in their socio-cultural environments into school science. The eco-cultural structure is as follows:

- Generating information about the pupil's everyday environment to explain natural phenomena
- Identifying and using the indigenous scientific and technological principles, theories, and concepts within the pupil's community; and
- Teaching the typical values of the indigenous community in relation to, and in the practice of, science and technology as human enterprises (Jegede, 1995).

In addition to the above, recommendations from different studies (e.g. Okebukola and Jegede, 1990; George, 1999b; George and Glasgow, 1988; Lawrenz and Gray, 1995; Ogunniyi et al, 1995; Proper et al., 1988; Aikenhead, 1996; and Cobern, 1993) were also included in the planning of the lessons. Among others they recommend that:

- Education in science should be viewed as the process of crossing the boundary between the sub-cultures of the learners and the sub-culture of the school (George, 1999b; Aikenhead, 1996)
- Such an approach should necessitate the provision of teaching/learning materials that are simple, relevant to context, and matching the developmental level of the learners (George, 1999b)

- Class discussions should include considerations of worldview cultural perspectives and other more metaphysical concepts (Lawrenz and Gray, 1995)
- The time for discussion in class be increased because of the differences in the perceptions of the learners (Lawrenz and Gray, 1995)
- The teaching manner and style should
    - Provide intellectual independence thus respecting the learners as thinking individuals (Proper et al., 1988)
    - Encourage active observation, interpretation, and explaining on the part of the learners (Proper et al., 1988)
    - Be accompanied by exposure to a variety of alternative modes of explaining so that the learners would test their views against other views (Proper et al., 1988)

This socio-cultural constructivist approach would require the teacher to become more aware of the learners' worldviews as related to science. Jegede and Okebukola (1991b) argue that becoming aware of a learner's worldview is necessary because the worldview or belief is an important "primitive initial scheme" that can colour the learners' way of looking at natural phenomena. Proper et al (1988) assert that every worldview or belief that students do not learn about reduces their ability to explain and interpret their experiences. This suggests that the teacher would have to encourage the learners to talk about how what they hear from their science classes compares to what they believe the world to be like. Such frank discussions would lead to improved understanding for both the teacher and the learners. This implies that the teacher would need to increase the amount of discussion that takes place in the science class. These discussions should lead to a consensus on the terms and concepts used to explain the phenomenon, and should include the considerations of worldview cultural perspectives and other metaphysical concepts.

1. Introduction

- **Use of set induction technique based on learners' immediate socio-cultural environment.**
- **A class discussion to discover the learners' beliefs, attitudes, and worldviews about the setting used.**
- **Making a link between the discussion and the day's topic**

2. Lesson development

- **Concept delivery intermingled with applications to the traditional setting discussed during the lesson introduction**
- **Use of various examples from learners' socio-cultural environment to reinforce concept acquisition**

3. Summary/ Conclusion

- **Discussing the main points and concepts of the lesson**

4. Evaluation of objectives

- **Students to work out questions based on the lesson's objectives, which have been made relevant to their socio-cultural environment**
- **The construction of a concept map was included in some of the lessons**

Fig. 4: Steps in a Typical Lesson Plan

As mentioned earlier, Cobern (1996a) argues that if such discussions are student-led and encourage a kind of "Socratic exchange" that is valued, encouraged and practised, they could bring the learners' beliefs to the surface in order to be examined by the teacher, peers and by the learner him/herself. Moreover, such discussions could help the science teacher to actually enlist these cultural perspectives to support his/her science teaching. A typical lesson plan based on the views discussed above followed the format presented in Fig. 4 above.

3.6.3 A description of a typical lesson

A typical lesson used a socio-cultural constructivist approach that depicted science learning as a process of border crossing from a learners' traditional worldviews to a scientific worldview found in a science classroom (Aikenhead, 1996). According to Aikenhead (2000), the approach would have a

> …View of school science that emphasizes the interaction between western science and the culture of students. A student's experience with school science is seen as a cultural event that strives to help students create new meanings about their world in terms of their cultural identity (p.245)

In this approach, the subjects were exposed to new science concepts that resulted in situations where the commonsensical knowledge, traditional worldviews as well as scientific worldviews lay *contiguously* in their minds (Ogunniyi, 1999,2000). Some type of *border crossing* was presumed to have taken place with the dominating worldview in that particular instance eventually leading each learner towards a certain type of *collateral learning* such as parallel, secured, simultaneous or dependent (Jegede, 1995). See chapter five for a more detailed description.

For the lesson introduction, the teacher used the set induction technique, which included: providing a brief review of past learning, asking thought-provoking questions and brainstorming. The subjects were encouraged to voice their views in class discussions by basing the topic under discussion on the learners' immediate socio-cultural environment. If misconceptions or alternative conceptions surfaced, they were attended either by the teacher or by their peers. The teacher would then make a link between the introduction and the day's topic. The aim of the introduction was to trigger a *contiguity-learning* (Ogunniyi, 1995, 2000) situation in which the subjects would possibly allow their traditional worldviews and the science worldview to lie contiguously so that some kind of *border crossing* (Aikenhead, 1996) e.g. smooth, manageable, hazardous or impossible, would start to take place in their minds.

During lesson delivery or process, concepts were taught by intermingling them with applications to the traditional settings that were discussed during the lesson introduction. Various examples were used from learners' socio-cultural environment to reinforce concept acquisition. For example: the door was used to illustrate moment of a force; the wheelbarrow to illustrate moments of a force; fetching water from the river to illustrate energy changes, etc. This provided opportunities for the subjects to relate scientific concepts to their life experience especially their cultural and traditional practices. This was appropriate for *contiguity learning* (Ogunniyi, 1995, 2000) in the sense that the subjects were given the chance to integrate their cosmological worldviews, science, and commonsense-intuitive knowledge in the descriptions and explanations of natural phenomena depicted by the concepts of force, energy, work and power. It was hoped that this would result in *border crossing* (Aikenhead, 1996), and eventually into some kind of *collateral learning* (Jegede, 1995), e.g. parallel, simultaneous, dependant or secured. The inclusion of visual, audio and hands-on activities provided opportunities for different learning styles that catered for the subjects' cognitive, psychomotor and affective needs.

The subjects were given varied learning experiences such as the chance of doing experiments and of expressing their conceptions of the various scientific concepts in the form of a concept map. The concept map in this case was used as a cognitive strategy in the sense that the subjects might have selected relevant information from the scientific concepts of force, energy, work and power presented by the teacher. Fairbrother (2000) has argues that during a cognitive learning strategy, the learners "elaborate and organize the information to add coherence, integrate new information with existing knowledge" (p7). The subjects also participated in some group discussions with peers and/or group work activities, which brought in the social as well as symbolic elements of communication (Duran, Dugan and Weffer, 1998). As Tobin (1996) has observed:

> Science can be regarded as form of argument during which ideas are formulated and the argued out in a social forum in which efforts are made to persuade peers to a particular point of view…If science is viewed as a form of discourse then learning science can be considered as learning a new way to make sense of experience. Discourse as it is used here refers to " a social activity of making meanings with languages and other symbolic systems in some particular kind of situation or setting" (p.31)

Other learning experiences included identifying and highlighting key points in the presentation by writing them on the board, or in a handout (Eggen and Kauchak, 1994). Sometimes the subjects were given a chance to work on the board and to also do the presentations of the outcomes of some of the activities they had carried out (e.g. concept maps and experimental results). Clear instruction of tasks such as how to carry out certain experiments and activities like constructing the concept maps, were done by keeping verbal descriptions short enough and slow enough for the learners to prevent their minds from becoming overloaded, and also addressed problems of language by sometimes using their mother tongue (siSwati) for further clarification (Rollnick and Rutherford, 1996).

During the lesson evaluation, the application of scientific knowledge was given in contextualized form as discussed in the construction of PAT (section 3.4.2). The evaluation also included the development of process skills such as calculations, drawing and interpretation of graphs, experimentations, making hypotheses, predictions, inferences and designing investigations, and problem solving activities. In addition to all these the subjects were given opportunities for constructing some concept maps.

3.7 CONCLUSION

This chapter included all the procedures and instruments that were used to collect the quantitative and qualitative data for this study. It provided details about the development of the various instruments used in the study viz: the My Idea About Nature (MIAN), the Physics Achievement Test (PAT), and the videotape recorder. It also provided a brief account of the instructional strategies of concept mapping and the cultural approach that were used as an intervention or treatment for the experimental and second control groups on the topic of force, energy, work and power.

The socio-cultural constructivist approach seemed very effective judging from the fact that the subjects were able to freely participate in the class discussions as they related some of the science concepts to their everyday experiences. Even though there was no instrument designed for the purpose to check this, the subjects seemed to enjoy the instructional strategy. Although time was limited, the concept maps seemed helpful. However, the researcher experienced difficulties in introducing it to larger classes. Better results could have been achieved by increasing the number of periods used for introducing the concept and the period for the intervention. Further, as Leach and Scott (2000) have observed, comparing the effectiveness of a teaching strategy with a more traditional approach has some limitations such as the uniformity of the quality of teaching. They argue that it is possible that any observable differences between the experimental and control groups could be due to the subjects' reaction to the teacher rather than the teaching strategy used. Besides that:

> Learning science often creates difficulties: the learning outcomes which follow from instruction are often disappointing in terms of how much students understand; how much they are able to apply; and how much they are able to remember (Leach and Scott, 2000:44)

The research instruments were very effective. The MIAN responses revealed the envisaged subjects' worldview presuppositions and the PAT proved viable in testing the effect of the intervention on the treatment groups. The video sessions were very successful in the sense that the subjects were able to freely voice their view concerning the phenomena under discussion despite poor lighting conditions. The researcher was able to glean a lot of information from the subjects' responses.

An unexpected outcome was that the three groups had a variety of subject combinations even though they learnt the same syllabus. The control groups consisted of learners who had opted for the syllabus while the learners from the experimental group had not been given a chance to choose, i.e. the syllabus was compulsory for them. In the course of the intervention, the researcher also discovered that quite a number of the learners were repeaters. This obviously seemed to have an effect on their performance in general and also on the research outcomes. However, the researcher does not see how this could have been avoided seeing that the sample selection was limited by a lot of circumstances beyond her control such as the number of schools within the region under study and the case of intact classes. The next chapter will present the results of the study and the data analysis.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

This chapter presents the findings of the study in terms of descriptive and inferential statistics, as well as excerpts derived from the responses of the subjects to the questionnaire, the physics achievement test, and the videotaped group discussion. The analysis reported in this chapter attempts to answer the following questions:

- What is the nature of the conceptions held by Swazi high school students on selected natural phenomena?
- Is there a significant difference between the scientific and traditional views about force, energy, work and power held by the learners exposed to an instructional model and those not so exposed?
- Do the learners' sex, age group, and interest in science influence their traditional and scientific worldviews about force, energy, work and power?
- How applicable are three cognitive theories/hypotheses (i.e. border crossing, collaterality and contiguity) to the learners' conceptions of force, energy, work and power?

In pursuance of these questions the findings of the study are presented in the form of tables or excerpts and their implications are then discussed afterwards.

4.2 AN OVERVIEW OF THE STUDY

A total of 128 fourth year high school learners enrolled in the Cambridge O' Level

Physical Science Syllabus were used as subjects of the study. Their ages ranged from below 16 years to above 23 years. The subjects were assigned to three groups: the experimental group (E), the true control group (C_1), and the group controlling for the pre-test effect (C_2). The design adopted a quasi-experimental design because the three groups constituted intact classes and as such could not be randomly selected. The experimental group (E) consisted of 51 students and of this 27 were males and 24 females. Of the 46 students in the true control group (C_1) 21 were males and 25 females. The second control (C_2) had 31 students of which 19 were males and 12 females.

The schools, from which the three groups were selected had identical characteristics and were quite comparable in terms of socio-cultural environment and past external examination results. Also they were selected because of their convenient location since the researcher had to teach E_1 and C_2 in close succession. The overall pre-test results indicate that the groups were relatively comparable (see Table 2). The pre-test means of both the experimental group (E: 9.26) and control group one (C_1: 10.12) are quite close. The comparability of both groups is further confirmed by a t-value of 1.107 compared to a critical t-value of 1.66 needed to reject the null hypothesis (Ho). The t-value suggests that there was no significant difference between the two groups.

Table 2: Overall Pre –Test Results on the Physics Achievement Test on concepts of Force, Energy, Work and Power

Group	N	Mean	S.D	t-test
E	51	9.26	4.65	t_{obs}(1.11)
C_1	46	10.12	4.03	
Entire group	97	9.69	4.34	

t_{crit} (1.66) at $p < 0.05$
$t = 1.11$ at $p > 0.05$

Due to policy constraints, details about the school culture, though important, could not be studied, as the researcher would have liked. Despite these constraints, spirited efforts were made to ensure that the videotaping captured classroom transactions as much as possible.

At the beginning of the study all the subjects answered a questionnaire on their ideas about certain natural phenomena. They were then all exposed to the same content of the Cambridge Ordinary Level Physics course section on Force, Energy, Work and Power. This was taught over a period of six weeks in 18 lessons i.e. one double period and one single period per week. Both the experimental group (E) and the first control group (C_1) wrote a pre-test and a post-test to test their achievement with respect to the content of these topics. The second control group (C_2) only wrote a post-test. The experimental treatment, involving exemplary instructional strategies (see chapter three), was administered to E and C_2 and was taught by the researcher. This was to ensure researcher control over the experimental treatment (Fraenkel and Wallen, 1993; Tuckman, 1978). The class teacher at the school taught the second control group (C_1) on the same topics using the typical lecture method.

4.3 WORLDVIEW PRESUPPOSITIONS HELD BY THE SUBJECTS

This section attempts to answer the following research question: What is the nature of the conceptions held by Swazi secondary school students on selected natural phenomena? The questionnaire that was used to investigate the nature of worldviews held by the subjects on certain conceptions about natural phenomena is a modified version of the " My Idea About Nature" (MIAN) questionnaire (Ogunniyi, 1999) that had been used by the Science and Technology Literacy (STL) Project to collect data in the various provinces of South Africa (see Appendix 1). It was administered to all the subjects before they were taught the topics under study. The MIAN is made up of eight fictitious stories about selected natural phenomena. Each subject was asked to read each fictitious story carefully and to express Agreement (A), Disagreement (DA) or Don't Know (DK) option with respect to the response choices listed under each of the eight fictitious stories. For triangulation purposes, the subjects were requested to express their own opinions about each story. The themes in each of the eight stories are as follows:

- Story One: The "mysterious" disappearance of people and animals in a dam
- Story Two: The controversy about the blue-red train phenomenon
- Story three: The sudden appearance of a friend being thought about
- Story Four: Tales of after-life experiences
- Story Five: The curing of a girl suffering from acute hysteria
- Story Six: The germination of peanut seeds in a magnetic environment
- Story Seven: Animals' reaction to environmental disaster
- Story Eight: Glowing materials in space.

The patterns of the subjects' response choices for each story are displayed in Figure 5. An examination of Fig. 5 reveals that the subjects seemed to agree in a descending order with the options under stories three, two, seven, five, one, four, eight and six. The highest disagreement was in story six followed, in descending order, by stories four, five, eight, one, two, three, and seven.

The responses of the subjects to the eight fictitious stories were then grouped into five major themes or categories. Each of the five response choices or options under each

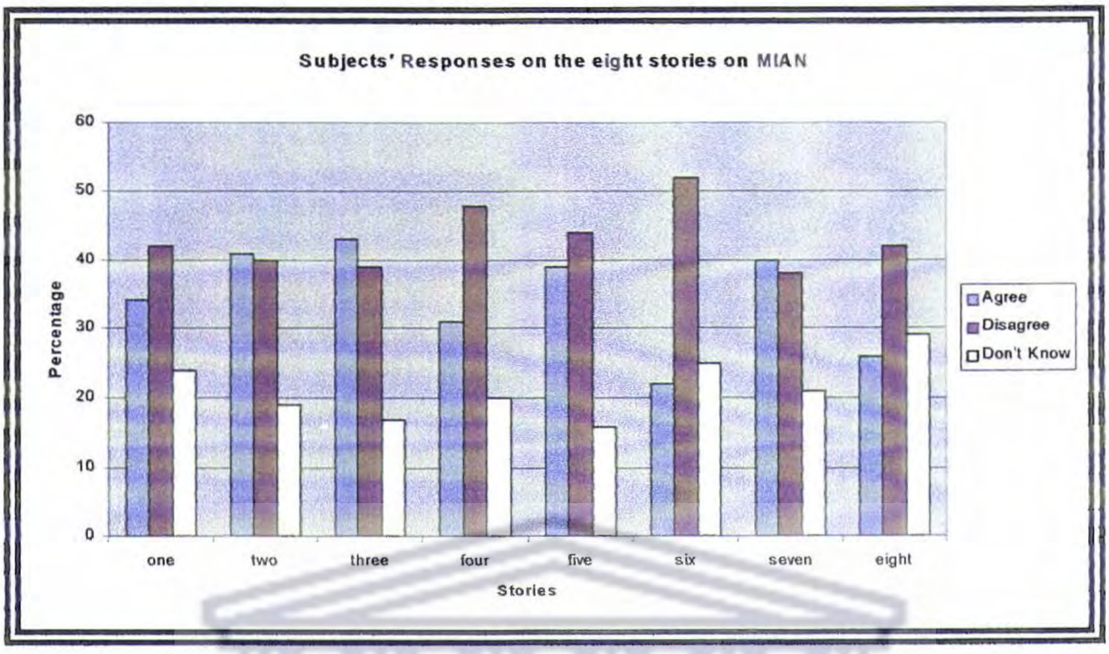


Fig. 5: Pattern depicting the subjects' responses on the eight stories on MIAN

story was assigned a number, which resulted in a total of forty items. The grouping was to reduce the possible influence of under- or overrepresentation of certain presuppositions (Ogunniyi et al., 1995). The categories were as follows: Magic and Mysticism (items 4,7,9,10,15 and 38); Metaphysics, Parapsychology and Pseudo-science (items 11, 12, 14, 16, 26, 27, 28, 29, 32, 35, 36, 37, 39 and 40); Spiritism (items 1, 3, 5, 18, 19, 20, 21, 22, 23, 24, 30, and 33); Rationalism (2, 6,13, 25) and Science (8,17, 31, 34). These categories were validated by a group of five science educators as mentioned in chapter three yielding a reliability coefficient of 0.80 using the Spearman Rank Difference reliability technique.

No doubt, re-grouping the various items of the MIAN could have a blurring effect on the specific categories but as Ogunniyi et al (1995) have argued, the relative reduction of the effects of these larger categories does not seem to reduce the emergence of discernable response patterns. The patterns of the subjects' response choices for these categories are displayed in Figure 6 below.

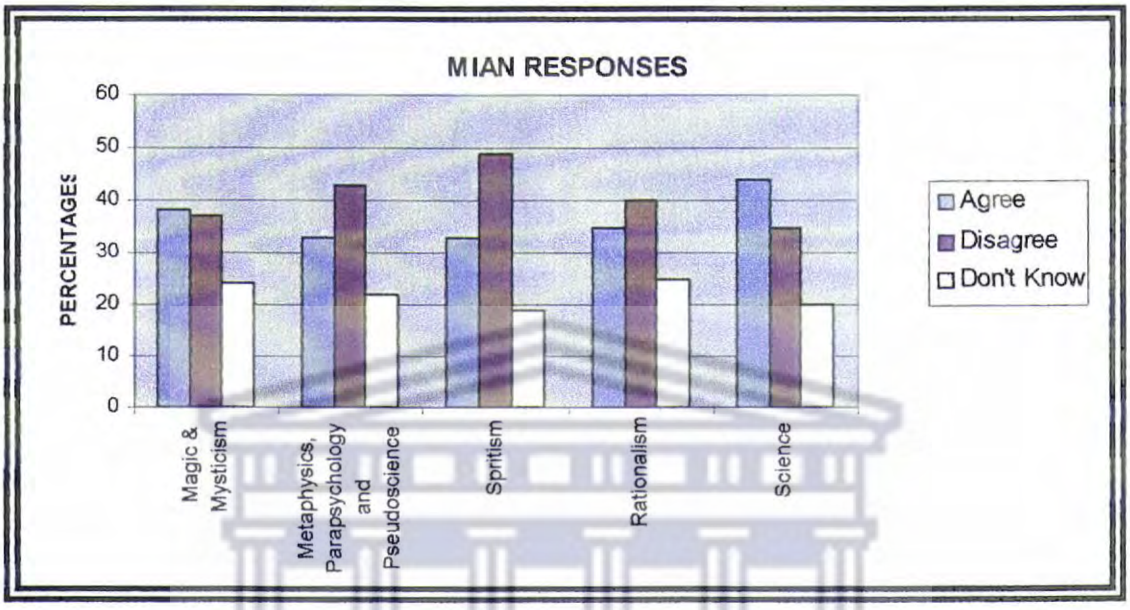


Fig. 6: Pattern depicting the subjects' worldview presuppositions about natural phenomena

An examination of the percentage of response choices in Fig. 6 shows that the subjects of this study held a multiplicity of worldview presuppositions. For example, the subjects seemed to agree in an ascending order with statements dealing with metaphysics, parapsychology, pseudo-science; spiritism; rationalism; magic/mysticism; and finally, science. Hence, as in earlier studies (e.g. Ogunniyi and Yandila, 1994; Ogunniyi et al, 1995), the subjects of this study held a variety of worldview presuppositions including scientifically valid viewpoints. It is worth noting, however, that with the exception of science, magic and mysticism, the disagreement percentages are higher on all the other worldview presuppositions than the agreement percentages. The spiritism category had the highest disagreement percentage followed by metaphysics, parapsychology, pseudo-science, rationalism, magic and mysticism, and lastly science. The magic and mysticism category had almost the same amount of subjects that agreed and subjects that disagreed with the items. The rationalism category attracted the highest percentage of indecision among the subjects with respect to the alternative response choices. This might be a reflection of the subjects' poor understanding or the direct influence of other rival worldviews on their response choices. In consonance with earlier findings (e.g. Ogunniyi, 1987; Ogunniyi and Yandila, 1994; Ogunniyi et al, 1995; Jegede and Okebukola, 1991a; George, 1999b) the subjects of this study held disparate and inconsistent worldviews. However, it is worth noting that the subjects seemed to express themselves freely rather than stick to any particular worldview pre-supposition. This is probably why Ogunniyi (1988) revised his earlier harmonious dualism theory as it suggests only two juxtaposed worldviews. It is perhaps for the same reason that he criticizes Jegede's (1995) Collateral Learning Theory, which also suggests two co-existing thought systems rather than a multiple of thought systems or what he called " multi-lateralism" (Ogunniyi, 1997; 2000).

The findings of this study are similar to those of Ogunniyi et al. (1995) where the subjects agreed more with statements dealing with science than with the other statements. They differ in that the subjects in the latter study also agreed with statements dealing with metaphysics, parapsychology, and pseudo-science while the subject of the present study also agreed with statements dealing with magic and mysticism. Although the subjects of this study seem to slightly resemble those of Bandiera et al (1999) where the subjects favoured a more rational and scientific worldview over other worldview presuppositions, they also favoured a magical and mystic worldview.

Assuming that the pattern of responses observed in this study reflected the views held by the subjects, it is likely that the subjects were influenced by both scientific and traditional worldviews (Ogunniyi, 1987). For example, in Fig 6 while on the one hand, about a two fifths (44%) of the subjects agreed with the scientific statements, about the same proportion (i.e. between 35% and 38%) agreed with alternative worldview presuppositions. The possible cognitive conflict that might arise as a result of the subjects holding a multiplicity of worldview pre-suppositions has been a matter of intensive debate in the extant literature (e.g. Aikenhead, 1996; Aikenhead and Jegede, 1999; Cobern, 1993; Ogawa, 1986, 1995; Ogunniyi, 1987, 1988; Ogunniyi et al., 1995; Waldrip and Taylor, 1999, etc). The main thrust of this debate under the general rubric of "border-crossing" and associated hypotheses will be discussed later in the chapter.

Table 3: Subjects' Worldview Presuppositions According to Gender

Categories	Males (%)			Females (%)		
	A	DA	DK	A	DA	DK
1.Magic and Mysticism	37	39	22	41	34	22
2. Metaphysics, Parapsychology, Pseudoscience	35	43	21	32	44	23
3. Spiritism	33	48	19	33	47	19
4. Rational	33	40	26	36	40	23
5. Science	49	33	17	40	38	24

The MIAN was also analyzed according to three demographic factors: gender, age and interest in science. The percentage response choices on the MIAN analysis according to gender in Table 3 showed that there were more females (41%) agreeing with statements concerned with magic and mysticism than males (37%).

On the other hand, there were slightly more males (35%) in agreement with statements concerned with metaphysics, parapsychology, and pseudo-science than females (33%). The agreement on spiritism items was equal (33%) for both sexes while there were more males (49%) that agreed with the science category than females (40%). There were more females (36%) that agreed with the items in the rational category than males (33%). It is worth noting that, with the exception of the science category, there were more males that disagreed with the items in the various categories than those that agreed. On the other hand, there were more females that disagreed than agreed with the items dealing with metaphysics, parapsychology, pseudo-science, spiritism and rational categories than those that agreed with these categories.

The responses of the age groups to the MIAN (see Appendix 3: Table 2) show that the under-seventeen year olds demonstrated the highest percentage agreement (44%) on statements dealing with magic and mysticism, and the highest disagreement percentage (42%) with statements related to spiritism. All the other age groups had the highest agreement percentages with statements under the science category. These consisted of 50% for the seventeen year olds, 47% for the eighteen year olds, 44% for the nineteen year olds, and 42% for the above nineteen year olds. The least agreement was in the category of metaphysics, parapsychology and pseudo-science for the under-seventeen year olds (31%) and the seventeen olds (32%). The other age groups had the least agreement in the spiritism category (eighteen year olds, 22%;

nineteen year olds, 27%; above nineteen year olds, 19%).

When the subjects were compared according to their interest in science (see Appendix 3: Table 3), the high interest subjects expressed the highest agreement (47%) on statements dealing science, while the low interest group expressed the highest agreement (34%) on statements related to spiritism. With the exception of the rational category, the high interest group had higher agreement percentages than the low interest groups in all the other categories.

From the findings of this study it is evident that the subjects, regardless of their gender, age and interest in science, hold varying degrees of traditional as well as scientific notions about selected phenomena, that is, they hold a multiplicity of worldview presuppositions. All of these findings corroborate earlier findings that certain "demographic factors such as sex, religion, ethnicity may not be exerting as much influence on a person's worldview as expected" (Ogunniyi, 1987, 1988, 2002a: 69)

A further breakdown of the responses can be found in Appendix 2. In the following subsections, the responses to the items under each story will be analysed according to the following categories:

- Magic and Mysticism category
    - Magic is an art that purports to control or forecast natural events, effects or forces by invoking the supernatural. (The Webster Comprehensive Dictionary, 1995; Ogunniyi and Yandila, 1994; Jobe, 1962)

- Mysticism as dealing with phenomena beyond human knowledge or comprehension. It can also be regarded as "an appeal to unexplainable mystery" (The Webster Comprehensive Dictionary, 1995; Ogunniyi and Yandila, 1994)

- Metaphysics, Parapsychology and Pseudo-science Category
  - Metaphysical phenomenon is that which is beyond the physical or experiential. (Ogunniyi and Yandila, 1994)
  - Parapsychology is that human force that is not explainable by known scientific laws (Ogunniyi and Yandila, 1994)
  - A pseudo-science phenomenon is one that is a seemingly scientific notion but containing erroneous conceptions. (Ogunniyi and Yandila, 1994)
- Spiritism Category
  - An example of rare animism, which is a theory that inanimate objects possess spirits. It is also loosely regarded as a form of spiritualism, which is the belief that the spirits of the dead in various ways communicate with and manifest their presence to the living. It is an appeal to another world of gods, spirits, devils, ancestors, etc (The Webster Comprehensive Dictionary, 1995; Ogunniyi and Yandila, 1994)
- Rational Category
  - The term rational refers to the formation of opinions by relying upon reason alone, independent of revelation or authority, i.e., an appeal to reason and commonsense (The Webster Comprehensive Dictionary, 1995; Ogunniyi and Yandila, 1994)

- Science Category
    - The knowledge of facts, phenomena, laws, and approximate causes, gained and verified by exact observation, organized experience, and correct thinking as well as the appeal to mechanism, reductionism, formism, objectivism, empiricism (The Webster Comprehensive Dictionary, 1995; Ogunniyi and Yandila, 1994)

4.3.1 STORY ONE: THE "MYSTERIOUS" DISAPPEARANCE OF PEOPLE AND ANIMALS IN A DAM

The first fictitious story of the MIAN deals with the disappearance of people and animals in the Mantjolo dam. The items under this story fall under the magic and mysticism category and spiritism category.

4.3.1.1 Magic and mysticism category: item 4

Item four stated that the Mantjolo incident was one of those unsolved mysteries. A considerable percentage of the subjects considered the phenomenon to be a mysterious event. About two fifths of the subjects agreed with the statement asserting that the incident is one of those unsolved mysteries, 20% disagreed with it, and 35% were uncertain about whether or not to agree with the statement. Although about two thirds declared their position with regard to this option, about a third expressed no clear opinion. This relatively high percentage of uncertainty probably indicates a lack of clarity of the story or the inability of the subjects to declare a clear position on a phenomenon they lacked adequate information or experience.

4.3.1.2 Spiritism Category: items 1, 3 and 5

Item 1 stated that the people and animals disappeared in the dam because they had been caught up in another world. Item 3 stated that a seven-headed snake was responsible for this. Item 5 stated that ancestral spirits took the people and animals away. These options come under the general rubric of spiritism.

Although it was earlier revealed in section 4.3.1.1 that the subjects viewed this phenomenon as mysterious, in the present category they seem to hold diverse views about it. An inspection of their responses indicates they do not hold a spiritistic view with regards to items 1 and 5 since 72% and 58% disagreed, respectively, with the options while only 5% agreed with the former and 17% with the latter. One possible reason for the relatively high percentage of disagreement is that Swazis do not believe that animals can be transferred to another world. Instead, they believe that only ancestors, or the spirits of the dead, can live in the other world (Kuper, 1980, 1986; Marwick, 1966). On the contrary, it seems evident that some of the subjects hold a spiritistic view with respect to item 3 since almost half (49%) of them agreed with the option. They claim:

- *The seven-headed snake drowns the people so that it can drain their blood*
- *Because the people disappear without any trace on entering the dam without permission from the clan, this means that the seven-headed snake take them if it is not asked or told that someone has asked to enter the dam, it thinks its food for it*
- *I think the people who enter the river are eaten by the snake which leaves there and with help of the ancestors*
- *The people and animals have been taken by the snake that the Mnisi clan belive or worshipped and it is the way the Mnisi clan fed the snake*

According to Marwick (1966), Swazis believe that every clan has ancestral spirits that can manifest themselves in form of a snake. These snakes usually visit homesteads and are never killed. They can manifest their displeasure in several ways, one of which is the one described in the above statements. However, since the Mnisi clan is considered to be very powerful, their ancestral snake is believed to live in a big dam as the following subjects claim:

- *The Mnisi clan is of superior types. They have the God given powers and no one can act against their will like entering the dam's premises without permission. If you are lucky you die but if you are not you have bad luckies*
- *The people and animals are killed by this Mnisi clan for their own benefits like to be rich in business management*

From the foregoing, it is apparent that the subjects adhere to the beliefs of their communities that have been told down many generations. This is what George (1999b) found even with the Seablast science learners that they seemed to adhere to the practices and beliefs of their elders. This was also found in other earlier studies in the area (Hewson and Hamlyn, 1984; Jegede and Okebukola, 1989; Waldrip and Taylor, 1999). The above statements also seem to corroborate the views of Adeyinka, Kyeleve and Yandila (1999) who would have grouped this phenomenon under superstitious beliefs. These relate to strange but observable events that generate fear in the observers leading them to give inaccurate explanations of such events or to attribute the former to unseen forces and supernatural agents. The few (26%) that disagreed with item 3 argued that:

- *There is no snake that can be owned by somebody and live in natural habitat*
- *I don't think that the is an thing like a snake staying in water but people only fail to swim across*

Very few subjects also expressed uncertainty about these options (24% for item 1, 26% for item 3, and 23% for item 5), an indication that most of them were familiar with the phenomenon.

4.3.1.3 Rational category: item 2

Item 2 stated that the people and animals disappeared in the Mantjolo dam because they could not swim out and were therefore eaten by crocodiles. This is a rational explanation whereby an opinion relies on reason alone and not on revelation or experience. An inspection of the results reveals that slightly more than half (56%) of the subjects agreed with the statement.

- *The mysteriosly disappearance of many people and animals may be caused by deepness of the dam. The animals and people are eaten by the crocodiles because they are carnivores, they only eat flesh. The animals may only sink in the muddy bottom of the dam water, then caught by crocodiles*
- *I think the people disappeared due to failer to get out of the dam after washing or swimming or it is caused by the steepness of the dam floor and the forces ejected by the gravitational force*
- *The floor of the dam is made out of mud that reaches deep inside the crust such that the people and animals sink in it and are not able to come out*
- *If a person was called for to die in this way, I see no reason why we should believe all these things*
- *I thought that the people fled to their relatives, while the animal escape to other good pastures*

However about a third (33%) of the subjects disagreed with the statement and a tenth (10%) had no opinion.

4.3.2 STORY TWO: THE CONTROVERSY ABOUT THE BLUE-RED TRAIN PHENOMENON

The second fictitious story of the MIAN deals with the event of a blue train that went down the A-side of a deep valley and a red train that came out on the B-side of the same valley, which had only one railway track. The items under this story fall under the magic and mysticism category, rational category, and science category.

4.3.2.1 Magic and Mysticism category: items 7, 9 and 10

Item 7 stated that the incidence was strange and difficult to explain, item 9 stated that the whole event was a result of some magical influence while item 10 stated that it was one of the examples of the wonders of science. A considerable number of subjects seemed to regard the whole phenomenon as mysterious. About half of the subjects agreed with item 7 (51%) and item 10 (53%). About a third (33%) disagreed with item 7 and 15% expressed indecision, while a fifth disagreed with item 10 and a quarter expressed indecision. The responses below are representative:

- *This is just mysterious. I don't think something like that can happen*
- *It is because of the science act of wonders*
- *They could not see clearly where the first train which is blue went to*
- *The train was too long and when going it occupied both the A and B sides of the valley, the people thought it was another train whereas I think it just one train but long with two colours red and blue*
- *According to my understanding, I think there was only one train. Maybe the other side was red and the other one was blue, but as far as I'm concerned there was only one train*

Contrary to the fact that a considerable number agreed with the statements regarding this phenomenon as mysterious, 53% of subjects disagreed with the statement that the whole event is a result of some magical influence (item 9). About a third (32%) agreed with the option while 16% were uncertain about whether or not to agree. In all the viewpoints expressed about the blue and red train phenomenon, the subjects' traditional worldviews are quite varied. For instance, while some thought that the people were under the influence of alcohol or drugs others thought the audience had sight problems. The following statements are reflective of their viewpoints:

- *Difficult to believe or it might happen they were under the influence of alcohol, drug addicted, mentally disturbed or brain washed*
- *Maybe the people were drunk and kept on seeing the same train but couldn't remember its colour*
- *I think the people were colour blind*

- *Some people have poor eye sight such that they can not even differentiate colours which is most common to males*
- *I can suggest that eyes focus on a straight line, like making a hole then place a lighted candle on the other side you are going to see the light if it is on a straight line*
- *The people were short sighted and could not see distant objects clearly*

While a considerable number of the subjects appealed to rationality or mysticism others were uncertain because a blue train went down into the valley. There is no indication in the story to suggest that both ends of the train could not be seen as a result of its length. All that was indicated was that there was no sound to suggest the possibility of the wagons joining each other. Also, one item (item 8) suggests a possible repulsion caused by the magnetic terminals of two trains. This issue will be discussed in greater detail later on.

4.3.2.2 Rational Category: item 6

Item 6 stated that one possible explanation for the incidence was that a red train was hidden on the B-side of the valley and was not seen by the group of people who were watching what was happening. This explanation is rational, that is, it relies on the use of reason. An examination of the responses reveals that half of the subjects do not regard the phenomenon as one that can be explained through reason. They instead, as seen in section 4.3.2.1, viewed it as mysterious. In this regard, only about a third (32%) agreed with item 16 while about a fifth (17%) expressed indecision.

4.3.2.3 Science Category: item 8

Item 8 stated that there were two trains that pushed each other away because of repulsive forces exerted by their magnets. Even though this notion of magnetic repulsive forces is scientific, 42% of the subjects disagreed with it and instead attributed the phenomenon to other types of forces such as frictional forces. They asserted that:

- *Trains can't use the same road. And they can't attract each other with magnetic forces. The trains just lost breaks.*
- *I think the two trains were driven by force due to friction or the train was painted one side red and the other side blue*
- *The reversal of the red train was caused by its failure to overcome friction force*
- *It is because of the forces that the trains were existing to another. The blue train possessed a upward force to the red train while the red train possessed a downward force to the blue train. It was like a see-saw*

However, about a third (36%) of the subjects agreed with the statement that there were magnets exerting repulsive forces on the trains while about a fifth (22%) were uncertain.

4.3.3 STORY THREE: THE SUDDEN APPEARANCE OF A FRIEND BEING THOUGHT ABOUT

The third fictitious story of the MIAN deals with the sudden appearance of friend being thought about and whom one had not seen for a long time. The items under this story fall under the magic and mysticism category; metaphysics, parapsychology and pseudo-science category, and rational category.

4.3.3.1 Magic and Mysticism: item 15

Item fifteen stated that this event was a result of the strange world we live in. This phenomenon comes under the general rubric of extra-sensory perception or parapsychology. There are spirited debates about whether or not humans have the capacity to perceive or evoke natural phenomena beyond the senses (Goode, 2002; Zangari and Marchdo, 2001). Whatever the case, 62% of the subjects disagreed with the notion that this incidence was either strange or mysterious, 16% agreed with it and 23% expressed uncertainty about it.

4.3.3.2 Metaphysics, parapsychology and pseudoscience category: items 11, 12 and 14

Items 11, 12 and 14 state that the event occurred because of the parapsychological characteristic of the human mind in that: it recognizes things even before they are seen (item 11); it sees further than the eyes (item 12); and acts like a magnet or a special type of computer (item 14). Although the subjects were previously found in section 4.3.3.1 to view this phenomenon as mysterious, they seemed to also hold the parapsychological view proposed by two of the options. In this regard, 54% of the subjects agreed with item 11, and 67% with item 12 while only 44% agreed with item 14. They further supported their views by asserting that:

- *Our minds work very hard I say this because the brains as the main organ of thoughts knows thing before being seen as to what is it that it is thinking then tranfere this to the eyes that acts as the sight of an individual*
- *The mind is able to keep things in memoryi they can be in form of pictures or words. When you thin about them they appear in your mind*
- *I suggest that the mind is where information is stored and pictures. It is also intelligent and brilliant*
- *It is just natural feelings not knowing anything. Your mind was thinking but not aware that he was coming, so it happened just like dreams you dream at night you see it happen the next thing*
- *I agree with the statement in (12) because you can see many things with your mind than eye's like seeing your dreams come true*

From the foregoing, the subjects seem to be mixing up the processes of how a visual image is formed on the retina, on the one hand, and how information is stored in the brain, on the other. The Concise Oxford Dictionary (1990) defines the mind as the "seat of commonsense, thought, volition and feeling" (p.753), and defines the brain as an "organ of soft nervous tissue contained in the skull" (p. 134). Szasz (1996) argues that the "mind is neither brain, nor self, nor language, but the person's ability to have a conversation with himself – the self acting as both speaker and listener – the "I" and the "me" speaking and listening to one another" (p. 2)

However, an inspection of the results also reveals that a considerable number of the subjects did not agree with the parapsychological views about the event. For instance, about two fifths also disagreed with items 11 and 14. Furthermore, an inspection of the responses for item 14 revealed that almost the same percentage of subjects either disagreed (47%) or agreed (44%) that the phenomenon occurred because the mind acts like a magnet or a special type of computer. Those that agreed with the option portray a pseudoscientific worldview, which construes a phenomenon in a seemingly scientific but erroneous way (Ogunniyi et al., 1995).

4.3.3.3 Rational Category: item 13

Item 13 stated that the sudden appearance of the friend was just a coincidence. About a third of the subjects agreed with the statement, 22% disagreed with it, and 42% were uncertain. Some of the subjects that thought that this was just a coincidence asserted that:

- *I think my friend also remember me and I also remember her so it was double coincidence so for her dicided to come*
- *I think its because, sometimes if you are thinking of a person whom you really love, it can happen to her to be attracted by your feelings whilst not seeing you. Her heart and mind will also get the same feeling. Then she will decide visit you while you are also planning too*

Although about three fifths of the subjects declared their position one-way or the other with regard to this option, about two thirds expressed no clear opinion. This relatively high percentage of uncertainty probably indicates, as previously mentioned in the other sections, a lack of clarity of the story or the inability of the subjects to declare a clear stand on a phenomenon of which they have inadequate information or experience.

4.3.4 STORY FOUR: TALES OF AFTER-LIFE EXPERIENCES

The fourth fictitious story of the MIAN deals with stories told by people who claim to have died and come back to life. The items under this story fall under the metaphysics, parapsychology and pseudo-science category, spiritism category, and science category.

4.3.4.1 Metaphysics, parapsychology and pseudo-science category: item 16

Item 16 stated that these people were able to tell the stories because when they died their souls lived on. An inspection of the responses reveals that more than half (56%)of the subjects were in agreement with this metaphysical view. For instance, one of the subjects asserted:

- *I think its because immediately a person dies, some of the body parts will be still working while your soul had gone to the other world. And when the soul see the things that happens to you or see the brain will still record them as it will be still working*

This response reveals that the subject is of the view that the soul in this case is able to see; it is an operation agency, which is more than physical or natural, and that it acts in a supernatural way and goes beyond the laws of nature (The Oxford English Dictionary, 1978). Equivocal as this viewpoint maybe, it aptly echoes the findings of Ogunniyi et al (1995) that the world is metaphysical and spiritual to people living in traditional societies. To them the metaphysics is deductive in the sense that some aspects of life flow naturally from metaphysics. In this regard 31% of the subjects disagreed with item 16 while 11% expressed uncertainty on the item.

4.3.4.2 Spiritism Category: items 18, 19 and 20

Item 18 stated that people tell these stories because their spirits do not die with their bodies, they leave the bodies at death. Item 19 stated that the people had merely visited the other world. Item 20 states that the soul of a dead person returns to the owner because it is unable to find a body in the other world. These options come under the general rubric of spiritism.

Although it was earlier indicated in section 4.3.4.1 that the subjects viewed the after-life phenomenon as mysterious and metaphysical, their views in terms of spiritism were diverse since most of them agreed with one item (item 18) and disagreed with the other two (items 19 and 20). Sixty nine percent (69%) of the subjects that agreed with item 18, 19% disagreed and 10% were uncertain whether or not to agree with the option. This finding supports Mbiti's claim (as cited in Ogunniyi, 1987) that an African knows the basic elements of his/her religious life, which include the beliefs that there is a god, there are spirits, and that there is an after-life. This is especially true with the Swazis, as observed by Marwick (1966) and Kuper (1980, 1986). One subject's response was as follows:

- *Only their body dies but their spirits remains on the air observing lot of things outside*

Furthermore, 55% of the subjects disagreed that the people visited the other world (item 19) while 68% disagreed that their souls returned because they could not find a body (item 20). Some of them argued that:

- *People don't tell us the thruth because they can only tell us what they are e.g. a Christian would say he sees the people mentioned in the bible*
- *Upon my view, when a person is dead no other world to reach but the outgoing air just ocupear the athmosphare*

The same Siswati word is used for air and spirit. In this regard, 22% agreed with item 19 while 25% were not sure of the answer. Only 7% agreed with item 20, and 26% were uncertain whether or not to agree with the option.

4.3.4.3 The Science Category: item 17

Item 17 stated that people were able to tell these after-life tales because their brains had not stopped when they 'died', but had been able to store these experiences in the form of dreams. Although this notion was classified as scientific, about half of the subjects (50%) disagreed with it thus adhering to earlier spiritism and metaphysical categories. One subject asserted:

- *These people who die for a while are normally possesed by evil demons which disturbed there working of the brain then after they thought they had died. Even the bible reveals that a person have to die twice first the death of the body in earth and secondly the death of the soul in hell. This makes it clear that the soul die a long time after the body or flesh*

However, 28% of the subjects agreed with the option suggesting that the people's brains had not stopped while 22% were unable to declare their stand.

4.3.5 STORY FIVE: THE CURING OF A GIRL SUFFERING FROM ACUTE HYSTERIA

Story five of the MIAN deals with the story of a Swazi girl that was cured of acute hysteria (lihabiya) by traditional healers (tinyanga). According to Marwick (1966), the lihabiya comes as a result of a spell cast by a man who has been rejected by a girl to whom he has been making advances. The items under this story fall under the spiritism category and rational category.

4.3.5.1 Spiritism Category: items 21, 22, 23 and 24

Item 21 states that the girl could not be cured in a hospital but was cured by a traditional healer because traditional medicine is superior to modern medicine. Item 22 stated that a traditional healer cured her because the traditional healers (tinyangas) always know the cause of every disease. Item 23 stated that modern doctors could not detect activities of devils as tinyanga do. Item 24 stated that traditional healers do not deal only with those things, which can be seen, but also those that cannot be seen. These options come under the general rubric of spiritualism.

Judging from the results it seemed evident that the subjects hold diverse worldviews about the phenomenon since they agreed with two of the options as well as disagree with the other two. For instance, 79% and 61% of the subjects agreed with items 23 and 24, respectively, while less than a fifth disagreed with items 23 (12%) and 24 (18%) thus portraying a traditional worldview that is influenced by spiritism. Some of their comments on items 23 and 24 were as follows:

- *I agree with the statement above (23) that morden doctors cannot detect activities of devils as tinyanga can do. But they can help is someways. Traditional doctor has some spirits which are said to be evil so to be able to deal with evil, but modern doctors are concerned with medical aid of a sick person which is un-evil*
- *Acute hysteria is a sign of an evil spirit on a girl and then traditional healers are those who sometimes mutilate people in order to heal them and get money. So doctors can't cure the disease because they can't mutilate*
- *The doctors are not able to cure this disease because it is caused by demons which are unable to see but the tinyanga use demonic things to cure diseases they can easily cure it because they are used to demonic things*

- *Traditional healers work with devil, so their devils show them medicine to use to the sick person. Some times the traditional healers tell the person the reason why she/he comes to him, while doctors wait until you tell them*
- *Traditional healers are always shown the right medicine to cure a patient by their bones they are using. Their bones contains massages from sleeping people (emadloti)*
- *Traditional healers can treat sickness easily because they are not concentrated in treated medicine they moves everywhere mixing animals and plant and they know further because they believe in ancestors*

From the above statements, it seems as if the subjects are attributing healing by traditional healers as exorcism, that is, the expelling of demons from the sick. Their statements seem to be influenced by a Christian background.

Sixty percent (60%) disagreed with item 21 that traditional medicine is superior to modern medicine while 77% disagreed with item 22 that traditional healers are always conversant about the cause of every disease. Some of them based their arguments on hygiene, level of education and lack of research techniques. They argued that:

- *Traditonal healers is not of good health because they prepare muti and it can be used after two years, their place is not clean and they can transmit the disease by using the same raizors on every person they heal rather than in hospitals every equipment that was used is kept safely and dumped safety and their enviroment is clean*
- *For some doctors are superior than the traditional healers because they have more knowledge of using medicine unlike the tinyanga only wants money for nothing*
- *Sometimes you find that the tinyangas are not educated so they don't always know about the cause of every disease*
- *No because the traditional healer sometimes lie and they do not know how to heal other diseases*
- *I suggest that the traditional medicines only treat for that time and they do not bother about the cause of some diseases.*

Less than a quarter of the subjects agreed with items 21 (24%) and 22 (16%). They believe that the traditional healers are able to conjure evil spirits and send them to possess other people, thus confirming Mbiti's (cited in Ogunniyi, 1987) statement that part of the African's basic belief include invisible forces of nature that can be tapped and used by man either beneficially or maliciously. This is evident in the following excerpts:

- *The one who did this to the girl got the medicine from the same traditional healer and he could easily heal something he did himself quite simple and it might be difficult for a doctor because the disease is man made the traditional healers make people to suffer from this diseases*
- *It is because sometimes you may find that those tinyangas are those who have send this acute hysteria and they know how to treat it. But they are not more than modern doctors.*

According to Marwick (1966), it is admitted that very few of the ordinary traditional doctors succeed in curing Lihabiya (acute hysteria), and it is only the traditional doctor who gave the man the medicine who can undo the mischief. The cure is usually in the same form as the spell.

The subjects demonstrated a very low level of uncertainty (16% for item 21, 8% for both items 22 and 23, and 19% for item 24), thus revealing that the majority was familiar with the phenomenon.

4.3.5.2 Rational category: item 25

Item 25 gives a rational explanation for the incidence asserting that it occurred because the doctors were too proud to find out about the sickness from traditional healers. Nevertheless, an inspection of the results shows that slightly more than half (54%) of the subjects disagreed with the statement. They argued that:

- *Doctors are more educated than traditional healers so cannot ask anything from people who know nothing like traditional healers*
- *It might because this girl didn't believe that she will be helped by the hospital medicine but she believed on tinyangas*

About a fifth (17%) agreed with the explanation while 29% expressed some indecision.

4.3.6 STORY SIX: THE GERMINATION OF PEANUT SEEDS IN A MAGNETIC ENVIRONMENT

The sixth fictitious story of the MIAN deals with the germination of peanut seeds that had been put in a box containing magnets. The items under this story fall under the metaphysics, parapsychology and pseudo-science and spiritism category.

4.3.6.1 Metaphysics, parapsychology and pseudo-science category: items 26, 27, 28 and 29

Item 26 stated the peanut seeds germinated faster than those not kept in the box because the magnets speed up their ability to do so while item 27 asserted that the magnets put a vita (powerful) force inside the seeds. Item 28 stated that the force of the magnets acted like the trigger of a gun while item 29 suggested that the force of the magnets and some other unknown forces caused the seeds to germinate faster.

An examination of the subjects' responses reveals that they did not agree with these pseudoscientific explanations proposed in the statements above. As such, about two fifths (45%, 41%) disagreed with items 27 and 29, respectively, while slightly more than half (52%) disagreed with item 26 and 28. Less than a third of the subjects agreed with all the options (item 26: 23%; Item 27: 32%; item 28: 21%; and item 29: 19%).

Although about three fifths of the subjects affirmed their position with regard to item 29, about two fifths (39%) expressed no clear decision. Once again, this relatively high percentage of indecision probably indicates a lack of clarity of the item or the inability of the subjects to declare a clear position on a phenomenon they lacked sufficient information or experience. Subjects that were not certain about the rest of the items were 25% for item 26, 23% for item 27, and 21% for item 28.

4.3.6.2 Spiritism Category: item 30

Item 30 depicted a spiritism notion. It stated that the gods living in the farm or soil caused the seeds to germinate faster. The results revealed that the subjects did not hold this view. In this regard, 70% disagreed with the statement, 14% agreed with it and 16% expressed uncertainty.

4.3.7 STORY SEVEN: ANIMALS' REACTION TO ENVIRONMENTAL DISASTER

The seventh fictitious story of the MIAN deals with the reactions of animals to changes like heavy storms and hailstorms or other unfavourable weather conditions. The items under this story fall under the metaphysics, parapsychology and pseudo-science category, spiritism category and science category.

4.3.7.1 Metaphysics, parapsychology and pseudo-science category: items 32 and 35

Item 32 stated that animals detect changes in the environment faster than human beings because they are closer to nature than human beings. Item 35 stated that this happens because animals were once super human beings with the ability to know things. These views fall under the general rubric of metaphysics in the sense that the animals' reactions are explained as transcendental, that is, lying beyond the bounds of all possible human experience or knowledge (The Webster Comprehension Dictionary, 1995).

Judging from the subjects' responses, it was apparent that they held diverse views about these views. For instance, 46% of the subjects agreed with item 32 thus revealing a metaphysical worldview while 56% disagreed with item 35, revealing the contrary. They instead, came up with reasons that were either alternative conceptions or religious, such as:

- *It is because animals' body temperature is high so it is easily dertimine the rate in which temperature will be cooled by what conditions*
- *Animals have many talents or blessings than us*
- *Its because animals have some forces that are being disturbed by the weather. And some of the parts of the animal will be affected, so the animal will then run away for it*
- *This is because they are given by God the sensitiveness more than us (their motion of attraction is closer to the earth) I disagree because we know that upward and downward forces are equal*

Thirty eight percent (38%) of the subjects that disagreed with item 32 and 16% were uncertain. About 9% agreed with item 35 while about 35% were not sure of the answer. Once again, this relatively high percentage of uncertainty might be a result of the subjects' lack of understanding of what the item required or possibly an unwillingness to commit themselves on a phenomenon about which they have inadequate knowledge.

4.3.7.2 The Spiritism category: item 33

Item 33 stated that animals were able to react the way they do because they have spirits that warn them about coming dangers. This notion comes under the general rubric of spiritism, which suggests that there are spiritual beings not detectable by the senses or characterized by the properties of matter (The Webster Comprehensive Dictionary, 1995). An inspection of the results shows that 42% of the subjects disagreed with the notion that the incident is due to animal spirits. To them the incidence was physical. One subject argued that:

- *This is because in most cases animals are kept outside shelter so it is more easily for them to identify danger*

On the other hand, 34% agreed with the option while 23% were uncertain whether or not to agree.

4.3.7.3 The Science category: items 31 and 34

Item 31 stated that animals react due to having more sensitive parts than human beings, and item 34 which asserted that this was because the animals' senses could detect slight changes in the wind or the earth. These options displayed a scientific view, which has also been adopted by the subjects of this study since 66% and 44% agreed with both items 31 and 34, respectively. For example:

- *I can deduce that animals have more sensitive parts than humans, because, when for instance a certain animal is about to be slaughtered it will go to far-off places*
- *Animals have been living outdoors for many decades so they know the different weathers outside their skins has become used to determine changes outdoor*

However, 19% of the subjects disagreed with item 31 suggesting that animals have more sensitive parts than human beings and 11% expressed indecision. Similarly, 29% disagreed with item 34 suggesting that animals' senses can detect changes in the wind while 11% were uncertain.

4.3.8 STORY EIGHT: GLOWING MATERIALS IN SPACE.

The eighth fictitious story of the MIAN states that some space probes have reported that certain materials glow or shine in space when human beings approach them. The items under this story fall under the magic and mysticism category, and metaphysics, parapsychology and pseudo - science category.

4.3.8.1 Magic and Mysticism Category: item 38

In item thirty-eight, the data revealed that the subjects were equally divided over the notion that the phenomenon happened because human beings have powerful forces in them that can affect things or people either for good or bad. In this regard, 34% of the subjects agreed with the statement, 32% disagreed, and 32% expressed uncertainty. This probably indicates, on the one hand, a lack of clarity of the story while on the other hand it might imply inadequate information or experience regarding the phenomenon.

4.3.8.2 Metaphysics, parapsychology and pseudoscience category: items 36, 37, 39 and 40

Items 36, 37, 39 and 40 explained the phenomenon using pseudoscientific views. Item 36 stated that the materials glow because human beings have things in their bodies that shine brightly like stars in the sky while item 37 stated that these substances could attract or push away things. Item 39 stated human beings are not the only beings living in the universe but there are others that live here too. Item 40 stated that human beings shine like the sun, moon and stars when they are in space.

An inspection of the responses reveals that the subjects held diverse views concerning this phenomenon. For instance, 43% agreed with item 39 thus portraying a pseudoscientific worldview (as has been the case of the so-called aliens from space) while more than half disagreed with Item 36 (60%) and item 40 (57%), thus revealing the opposite. Less than a third agreed with item 36 (10%), item 37 (28%), and item 40 (14%). Those that agreed with item 39 said:

- *This means that we are not the only humans in this world there are other plannets of which they are other people lives in those plannet too. Like we have Jupiter, Mars, Mercury, Venus, Earth. It means there are also people occupied those other universes*
- *It is because some people live in the universe not here on earth*
- *It due to their sight which attract and pull the shining of an object like the mirror they remove their sight fast away from the shining because of force in the affecting things*
- *Human beings are dark than materials in space so when they are approached by the materials, more light is needed to detect them*
- *It shows that the force of gravity is very low and the things may shine due to our less weight in the moon*
- *I believe that the whites had taken nature to be controlled by themselves. We Africans believe in many things that are strange like the one above but they ignore our ideas and come out with their whitish explanation of that particular thing. To my surprise the above statement is very strange. Its whites idea*
- *I agree because some human beings are beautiful and some have shadows and as they go up into the universe they change physical weight*

Although about three fifths of the subjects declared their position with regard to options 37 and 40, about a third (35% and 36%, respectively) expressed uncertainty. As previously indicated in other sections, this relatively high percentage of uncertainty probably reveals a lack of clarity of the story or the inability of the subjects to declare a clear position on a phenomenon of which they lack information. About a quarter (28%, 25%) of the subjects that was uncertain about items 36 and 39, respectively.

4.4 THE EFFECTS OF AN INTERVENTION ON THE SUBJECTS' UNDERSTANDING OF THE CONCEPTS OF FORCE, ENERGY, WORK AND POWER

This section attempts to answer the following research question: Is there a significant difference between the scientific and traditional views about force, energy, work and power held among Swazi secondary school students who have been exposed to different teaching and learning strategies? A Physics Achievement Test (PAT) in Appendix 3 was used to test the effect of an intervention on the subjects' understanding of force, energy, work and power. The PAT was administered at the beginning as a pre-test and at the end as a post-test. It is a criterion-referenced test in that it was constructed to measure a set of operationally or behaviourally stated objectives (Tuckman, 1978) on the topics of Force, Energy, Work and Power found in the Cambridge O'Level syllabus for Physical Science (see chapter 3). As mentioned earlier, the PAT represented a sample of actual performances (Tuckman, 1978) and measured the learners' achievements of the objectives, conceptions, process skills and applications (Klausmeier, 1980), which were structured to be in line with some aspects of the assessment framework used in the Science and Technology Literacy (STL) project (Ogunniyi, 1999). As already mentioned in Chapter 3, these are:

- The use of process skills to investigate
    - Use of graphical and symbolic representation
    - Accurate reading and/or estimation of common measurements
    - Planning scientific investigations
- The conceptions of scientific concepts and principles related to Force, Energy, Work and Power.
- The innovative application of scientific knowledge and skills.

from beliefs they have acquired from their socio-cultural environments and which have been passed down many generations? It looks as if these statements are outrageous and seem to contradict the observation made by several science educators (e.g. Jenkins, 2000; Gunstone and White, 2000; Jegede, 1995; Ogunniyi, 1995; Ogawa, 1986) that non-westerners do not completely abandon their traditional beliefs in favour of scientific ones in a learning situation but instead tend to seek ways of holding onto both belief systems in one way or another. After a review of studies in the area, Ogunniyi (1988) concluded from an earlier study that, "the scientific worldview may not completely displace the people's traditional world outlook even after a thorough exposure of the former" (p.7). Besides, the abovementioned statements seem to also contradict the socio-cultural constructivists' view that, instead of eliminating the learners' traditional worldviews,

- Science education should start from the learners' understanding of natural phenomena (Cobern, 1996a; Lawrenz and Gray, 1995; Jegede, 1995; Jegede and Okebukola, 1991b; Hacking and Garnett, 1985).
- Teachers should become more aware of the impact of cultural variables such as traditional beliefs and religious affiliations in their teaching efforts (Jegede and Okebukola, 1991a); and that they would need to increase the amount of discussion that takes place in the science class. (Cobern, 1996a; Lawrenz and Gray, 1995).
- The instructional strategies should meet the cultural background learners bring into the science classroom (Jegede and Okebukola, 1991a) so that the teaching of science using the socio-cultural mode could be used as a filter for eliminating the apparent mismatch between the information and ideas brought

mysteries of rain making" (p.62). Ogunniyi (1987, 1988) attempted to clarify the notion of African science by asserting that African science is a composite of diverse worldviews including what might be deemed scientific, mystical, parapsychological, religious, etc. In other words, there is no sharp demarcation with such a cosmology between the physical and rational world on the one hand and the metaphysical on the other.

Notwithstanding the positive arguments set forth, some researchers classify traditional beliefs as superstitions (Emereole, Munyadzwe, Ntingana and Mosimakoko-Mosalakgoko, 2001; Emereole, 1998; Adeyinka, Kyeleve and Yandila, 1999). According to the American Heritage Dictionary of the English Language (Morris, 1982), superstition is

> A belief that some action or circumstance not logically related to a course of events influences its outcome. (It is) any belief, practice, or rite unreasoningly upheld by faith in magic, chance or dogma (p.1292).

Adeyinka et al (1999) argue that in view of the fact that superstitions are not scientific but based mostly on magical, mystical and rational conceptions, and since they form an important component of alternative conceptions, it is essential for schools as "critical agents of change to disengage the minds of learners from such erroneous beliefs… in order to prevent interference with learning the science process" (p130-131). Awoyiku (as cited in Adeyinka et al., 1999:128) adds that the main job of the science teacher is either to eliminate such superstitious beliefs or to explain them in terms of natural phenomenon. One wonders about the viability of such statements. In view of contrary research findings, is it possible for the school system to eradicate all superstitious beliefs? Could teachers succeed in disengaging the minds of the learners are not incompatible. He discovered in an earlier study that the traditional worldviews of literate and non-literate Nigerians were not totally devoid of scientifically valid views of the universe. He also came to the conclusion that the scientific and traditional worldviews were not mutually exclusive of each other, and that the two thought systems may not always be in conflict with each other but that each system served some useful purpose even though neither is adequate for coping with all experiences. Further more, some researchers working in traditional societies have argued that traditional knowledge has contributed to society in many ways (e.g. Davis and Ebbe, 1995; Iwu, 1995; Zangari and Marchdo, 2001; Goode, 2002). According to Iwu (1995), traditional knowledge is of great value in its contribution to health and medicine. He argues that:

> The only thing that you can say that traditional medicine has in common with modern medicine is the fact that they both cure disease—one heals, the other treats. But, the role of the traditional healer is much broader than that of a Western medical practitioner. The traditional doctor is a healer, diviner, adjudicator, and a protector of his whole community. Therefore, it is only a part of the traditional healer's role that we are discussing when we compare them to modern doctors. (Iwu, 1995: 14)

Snively and Corsiglia (2001) add that there are plenty of traditional peoples' scientific and technological contributions that have been incorporated in modern applied sciences (e.g. medicine, engineering, architecture, plant breeding, and so forth).

However, as Emereole (1998) has observed, some writers prefer to use terminology like *African science* to describe such traditional knowledge, suggesting that Africans have or seem to apply a type of science different from school science. African science, according to some of Emereole's students, includes "things like superstitions, African medicine practiced by native doctors or *sangomas*, and things like the accord with a valid scientific view (Ogunniyi, 1995); and (2) that the conceptions held by non-western learners, in this case Swazi secondary school students, prior to formal instruction may, in part, be the result of traditional practices and beliefs existing in their communities and to which they were firmly committed (George 1999b; Lawrenz and Gray, 1995; Ogunniyi, 1995).

During a group discussion of the subjects recorded towards the end of this study, some of the subjects maintained that their cultural beliefs constituted a critical part of their identity as Swazis. As cited in the last chapter, they argued that western education should not be allowed to supplant their cherished cultural beliefs about their ancestors, traditional doctors and their methods of healing, and so forth. Other indigenous peoples from different parts of the world have expressed the same sentiment. For example, Davis and Ebbe (1995) argued that, "Traditional knowledge is related to the entire culture of a people, including its identity and spiritual and religious beliefs" (p7). They further contended that indigenous people see the traditional knowledge as part of their overall culture and vital to their survival as people, and as such the cultural values derived from this knowledge, and their rights to maintain these values must be acknowledged, respected and protected in the development process.

Numerous studies have pointed out that Africans, literate and non-literate, proffer scientifically valid explanations for traditional practices and natural phenomena taking place in their socio-cultural environments (e.g. Emereole, 1998; Emereole and Ontse, 1995; Ogunniyi, 1987, 1988). Ogunniyi (1988) has argued that, despite the differences between the scientific and traditional worldviews, the two thought systems this study, it is evident that the subjects regardless of sex, age and interest in science hold varying degrees of traditional as well as scientific notions about selected phenomena, that is; they hold a multiplicity of worldview presuppositions.

As already indicated in section 4.3, and assuming that the pattern of responses observed in this study reflected the views held by the subjects, it is likely that the subjects were influenced by both scientific and traditional worldviews (Ogunniyi, 1987). For example, while about a two fifths (44%) of the subjects agreed with the scientific statements, about the same proportion (i.e. between 35% and 38%) agreed with the alternative worldview presuppositions on the same phenomena. When their alternative conceptions were placed against a set of theoretical categories: magic and mysticism; metaphysics, parapsychology and pseudo-science; spiritism; rational; and science, it was also observed that the metaphysics, parapsychology, pseudo-science category attracted the highest percentage of indecision among the subjects. This might be a reflection of the subjects' poor understanding of the subject matter in question or the direct influence of other rival worldviews on their response choices. In consonance with earlier findings (e.g. Ogunniyi, 1987; Ogunniyi and Yandila, 1994; Ogunniyi et al, 1995; George, 1999b) the subjects of this study held disparate and inconsistent worldviews about these diverse natural phenomena.

From the foregoing, it seems that the subjects involved in this study were not immune from alternative worldview presuppositions, which probably exerted influence on their behaviours in certain contexts. Furthermore, these findings seem to corroborate earlier findings in the area, namely: (1) that students' worldview presuppositions tend to condition their understanding of natural phenomena, although such views may not

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

The first section of the chapter discusses a few issues relating to three of the four primary aims of the study, namely: the nature of the conceptions held by Swazi secondary school learners of selected natural phenomena; the effect of an intervention on the learners' conception of force, energy, work and power; and their traditional and scientific worldviews of selected natural phenomena. As a way of pushing the debate forward, the last section examines what is termed the "African Learner Model", a theoretical construct derived from the Border Crossing, the Collateral Learning Theory and the Contiguity Learning Hypothesis as espoused respectively by Aikenhead (1996), Jegede (1995), and Ogunniyi (1995). The so-called "African Learner Model" attempts to describe how and under what conditions an African learner cognitively crosses the border from his/her traditional worldview to the scientific worldview presented to him/her in the science classroom.

5.2 THE NATURE OF THE CONCEPTIONS HELD BY SWAZI SECONDARY SCHOOL STUDENTS OF SELECTED NATURAL PHENOMENA

One of the primary aims of the study was to explore, using the "My Idea About Nature" (MIAN) questionnaire, the nature of the conceptions held by Swazi secondary school students of selected natural phenomena. The responses of the subjects to eight fictitious stories were grouped into five major themes or categories as follows: Magic and Mysticism; Metaphysics, Parapsychology and Pseudo-science; Spiritism; Rationalism and Science (see Ogunniyi, et.al.1995). From the findings of investigation on whether or not demographic factors such as sex, age and interest in science had an influence on the subjects' performance on the topic of force, energy, work and power also showed that this was the case in all the factors except gender where there was no significant between the males and females in E in the pre-test stage, and C_2 in the post-test. Finally, the study also demonstrated that the three theories/hypotheses of Border crossing, Collateral Learning and Contiguity Learning are applicable to the way in which the subjects responded to the instrument. The next chapter will discuss a few issues that emerged from the data analysis. It will also describe a model based on the three theories/hypotheses discussed in the study.

- *Khangezile (Post-test): She might use energy from the sun to help push her carry the water. The container will be heavier after sunset*

What is more, it seems as if Khangezile was experiencing the dynamic interplay between or among dominant mental states constituting worldview template that probably governed her thoughts and actions (Ogunniyi, 1997). Perhaps the Swazi traditional worldview, commonsensical knowledge and the scientific worldview are being repositioned such that they ultimately lay contiguously. In other words, a sort of cognitive wrestling of schemata was probably occurring (Ogunniyi, 1995; Adams, 1999), which eventually capitulated to the dominant one, in this case, the scientific worldview in order to please the teacher.

From the foregoing, one can assume that the "bridging mechanism" between the two contiguous thought systems probably engendered the physiological and psychological interactions, which resulted in the variety of border crossing explained through collateral and contiguity learning theories/hypotheses. However, this postulation awaits further investigation.

4.7 CONCLUSION

Having all the points above, and based on the results of the "My Idea About Nature" (MIAN) questionnaire that was used to investigate the nature of the subjects' worldviews it can be concluded that the subjects of the study have alternative worldviews which probably affected the way they navigated the process of border crossing. Further, the results of the "Physics Achievement Test" (PAT) used to compare the treatment groups, seem to indicate some impact of the instructional strategies on the topic of force, energy, work and power. The results of the during the learning endeavour, in this case, during the group discussion. This interest probably made him to change his mind and to support Langa by moving from his previously scientific to a traditional worldview. The human interest being served here goes beyond just a casual attention. It includes ethos, motives, values, beliefs, fear of being ostracized, sense of social identity, and so forth (Ogunniyi, 2002b).

Another example of contiguity learning probably occurred when Khangezile, one of the subjects in E started scolding the group, saying that they must not answer foolishly because the teacher wanted to see if they had learnt the scientific concepts. She said this, holding her physics notebook, which she then opened and tried to explain the phenomena using the Physics notes copied from class. She said:

- *Khangezile: The witchdoctor was not right: he had heard rumours. Mr. Ngwenya, as our teacher said, he forgot to change the oil and the diesel. So the machine had maybe died or become tired. So it was unable to do work. What I can say is that in our Physics our teacher told us that efficiency is the work done over energy input. So the machine was doing less work than the energy put in due to petrol and diesels, which were not changed.*

(Excerpt from videotaped group discussion)

It seems as if Khangezile was serving a human interest: that of pleasing the teacher. The type of border crossing exhibited in this case is *hazardous* since the subject was unable to explain the phenomenon using her own words but instead relied on the notes she had taken in class. An investigation of her responses to questions 2.2 and 2.3 in the pre- and post-tests further revealed that she probably had experienced a hazardous border crossing. For instance:

- *Khangezile (Pre-test): The sun brings more energy. The wheelbarrow will be heavier than before in the sunset.*

The above excerpts seem to further demonstrate that the context under which a learner finds him/herself or the human interest being served (see next section) does have an effect on the type of border crossing which occurs on a given subject matter. A scientifically dominated context (a science test) might have influenced Langa to write commonsensical statements instead of traditional ones probably in order to pass the test.

4.6.3.3 Border crossing, Contiguity Learning, the Interest Shown and Human Interest

While one subject in second control group (C_2), Langa, was busy explaining the phenomenon about the chain saw using traditional worldview presuppositions, Mandla, a male who had started off by saying that he disagreed with Langa's witchcraft issue, later on changed his mind to support him. Mandla seemed to have suddenly shown interest in some of the traditional worldview presuppositions presented by Langa. The following statement from the videotaped group discussion made by Mandla reflects this cognitive shift quite graphically:

- *Mandla: I agree with what my colleague (Langa) said these beliefs in witchcraft whatever somebody says like for example I say a teacher comes to class and tell you that you have an ugly nose. No. This thing is going to make you to be mindful that she said that you are ugly. Because you know that your nose is ugly that thing is in my mind. So when Mr. Ngwenya was told that you will see wonders. The fact that he knew that thing, the witchcraft doesn't mean that I will have problems there. So it kept on disturbing. So he kept forgetting the service*

According to Ogunniyi (2002b), the psycho-metaphysical aspect of the interaction between the contiguous worldviews at play in Mandla's mind could probably be related to the interest he showed in Langa's traditional worldview presuppositions between the two thought systems will depend on the influence of the dominant worldview presuppositions or assumptions at work. Although Langa is holding on to his traditional worldview presuppositions, he seems to have also *managed* the border crossing between the two contiguous worldviews. The border crossing is *managed* in the sense that he was able to explain the phenomenon using correct scientific concepts, which he also used when answering question 8 in the test as follows:

- *Langa: He meant his saw was putting more power and the saw did less work.*

The *Contiguity Learning Hypothesis* proposed by Ogunniyi (1997) would explain this incidence as a dynamic interplay between and among dominant mental states constituting worldview template that govern Langa's thoughts and actions. Ogunniyi (1996) has suggested that the two apparently contradictory worldviews are repositioned such that they ultimately lie contiguously. Their level of overlap will depend on the effectiveness of the adaptive mechanism and the degree of equilibrium between or among the conflicting worldviews. The degree of equilibrium will, of course, depend on the adaptability at the points of 'contact' in terms of overall psychological, mental and emotional state experienced by an individual. In Langa's case, the traditional worldview template seemed to finally influence his explanations.

It is worthy to note that Langa's responses to Questions 2.2, 2.3, 9.6 and 9.7 were all commonsensical instead of traditional:

- *Langa (Q2.2 and 2.3): If the sunset it would be dark and that means time move and they should eat before they sleep. She would hardly see her way home and they can not cook on time.*
- *Langa (Q9.6 and 9.7): She respected her culture or she was moaning. Nothing could have happened but it would be a sign that she didn't care about her neighbours.*

context that was dominated by a scientific worldview because they were writing a science test in a school science environment. The scientific context triggered off their scientific schemata resulting in the subjects' responding with valid scientific concepts. The type of border crossing that occurred between the subjects' predominantly traditional worldview and that of school science can be classified in this case, as *manageable* because the subjects needed to achieve the social goal of passing the test even though the answers they were writing seemed to contradict or seemed irrelevant to their traditional worldviews (Aikenhead and Jegede, 1999)

The context for the videotaped group discussion for the subjects in C_2 was dominated largely by the scientific worldview presupposition. Most of the subjects, except one (Langa), tried to explain both phenomena using scientific viewpoint. However, they succeeded only in presenting an alternative worldview, which revealed a sort of *hazardous border crossing*. It is interesting to note that the general discussion had an effect on the one subject, Langa. For instance, he asserted:

- *Langa: But as far as I am concerned, the fact that the oil was old also contributed to the efficiency of the machine. Although the oil was also old it means that the machine was working with... because it was consuming less oil, which is old, and also producing less work. Then on the other side of this tinyanga people, I will say that they ...with the working of the machine. This inyanga, the Dlamini one, told Mr. Ngwenya that what he is going to see because he has insulted him, he has done wrong... He is going to see wonders, which means his... his chain saw. I say that this, ...in fact because why then at the end it was the chain saw that got the problem.*

(Excerpt from videotaped group discussion)

From the fore going, it seems evident that the predominantly scientific context made Langa to agree to both worldviews, hence confirming Ogunniyi's (2002b) argument that the type of border crossing that will result from the "bridging mechanism"

V: *Because she knew that she knew that she had done something wrong*

M: *Ya, I agree with you because if you actually believes in the ancestors, they are there if you are one of its believers. For example, people are in a accident, those who actually believe in them and obey, they are not likely to be injured*

G: *How can dead people participate like that*

M: *They can participate through their spirits*

V: *If you believe on that thing, if you do not believe it won't happen?*

L: *Yes, it won't. Zandile was not afraid just because she believed in this thing, she was afraid of her father that he will beat her*

V: *I think in Zandile's homestead they knew that if you bring water at night you will be punished by the ancestors and Zandile got late home, she knew that she would get the punishment*

M: *If Zandile's grandmother believes in this spirits, this was a punishment to Zandile*

C: *Let me ask this question, if Zandile wouldn't fall while entering the home, what her grandmother going to say?*

V: *I think a punishment was going to be... I think she was going to get that punishment at any time not on that particular day. At any time it would happen*

M: *Yes, yes. It was going to come about because they believed in it...the spirits are always there, guiding and looking*

V: *If you have done wrong to them they will punish you at time not at the same time*

From the above excerpt, it is evident that most of the subjects, mainly males, gave responses that were embedded in spiritism and metaphysics suggesting that traditional worldview presuppositions rather than scientific ones regarding this phenomenon dominated the context of group E during the class discussions as well as in the out-of-class context.

4.6.3.2 Border Crossing and Contiguity Learning in a Scientific Worldview-Dominated Context

An examination of the results derived from questions 2 and 8 in Appendix 8, reveals that the subjects performed better in the post-test (PAT) since more than four fifths were able to give a correct answer or part thereof for Q2.1 while more than three quarters did so for Q8. One may argue here that the subjects were influenced by a

- *S_{16}: It is because there is energy from the sun, so she did not have power or energy to push it*
- *S_{17}: It is because the water might have some dust particles & germs so it will need to be boiled for a couple of minutes. They might be sick and suffer from cholera because they get water from the river*

In the post-test, the same subjects' comments were as follows:

- *S_{16}: It is because of her parents' law. The ancestors of that home would not be there and bad things would happen.*
- *S_{17}: This is because it is a rule and a belief that this may bring lightning into the home. Her father and mother and any elder person can punish her*

When applying the *Contiguity Learning Hypothesis* to the above case, it can be assumed that the above subjects maintained a scientific mentality in the pre-test context by writing responses based largely on scientific assumptions they had learned in previous science classes. However, the contextual circumstances in which they found themselves between the pre-test and post-test period triggered off their traditional belief schemata, which then shifted their responses from being scientific to being traditional, i.e., their behaviours were then galvanized largely by traditional demand (Ogunnniyi, 2002b). In other words, these subjects were forced to adapt to the flux of change in their environment due to the dynamic and non-linear nature of the process of border crossing (Ogunniyi, 2002b). What is more, it would be reasonable to assume that the behaviour exhibited by the above subjects could have been a result of traditional worldview influence from the other subjects in the group during the period between the two tests, basing it on the fact that the context of experimental group (E) was mainly dominated by a traditional worldview as illustrated by the subjects' presuppositions in the following excerpt from the videotaped group discussion:

and psycho-metaphysical aspects, only the latter will be considered since the former is beyond the scope of this study. The discussion will concentrate on the interest shown by the subjects during the learning endeavour as part of the psycho-metaphysical aspect, on the dominant worldview presuppositions at work, and the human interest being served as a way of investigating the types of border crossings that might have taken place. Phelan et al's (1991) types of border crossings (i.e., managed, hazardous and impossible) as described in Aikenhead (1996) will be used for analysing the data.

4.6.3.1 Border Crossing and Contiguity Learning in a Traditional Worldview-Dominated Context

Ogunniyi (2002b), in his Contiguity Learning Hypothesis, argues that the dominant worldview in a given context is likely to affect the type of border crossing from one worldview to another. He further argues that the contextual circumstances in which a learner finds him/herself is likely to trigger off one or all of the three major schemata (i.e., traditional beliefs, commonsense – intuitive knowledge and science) found in his/her cognitive structures. Thus the variety of experiences to which a learner is exposed within a day might trigger off different schemata in given instances, depending on the dominating worldview at that particular point and time. What seems imperative is how the learner adapts to the flux of change in his/her contextual circumstances. Thus a learner in a traditionally dominated context might be influenced by the context to cross the border from a scientific worldview into a traditional worldview and vice versa. This was illustrated by the following case of some the subjects (S_{16} and S_{17}) from E, who had started off with scientific comments in the pre-test of the PAT and ended up with traditional comments in the post-test. These subjects' comments in the pre-test were as follows:

fast, which have different meanings to that of the scientific concepts of power, work, and rate.

4.6.3 BORDER CROSSING AND THE CONTIGUITY LEARNING HYPOTHESIS

Ogunniyi (1997) has argued that while a number of theories and hypotheses have provided a useful description of how learners relate their traditional worldviews and that of school science, they have not gone deep enough to explain the actual mechanisms or processes of border crossing, e.g., the "Collateral Learning Theory" by Jegede (1995); the "Cognitive Conflict Model" by Ogawa (1986); and the "Harmonious Dualism Hypothesis" by Ogunniyi (1988). He has since posited "the Contiguity Learning Hypothesis as a plausible explanatory model for cognitive border crossing" (Ogunniyi, 2002b, p.1)

According to Ogunniyi (2002b), the Contiguity Learning Hypothesis regards border crossing as a dynamic and non-linear learning process evinced by interacting worldviews in a given context. He further claims that the type of border crossing that will result from the "bridging mechanism" between the two thought systems will depend on "the influence of the dominant worldview presuppositions or assumptions at work and the human interest being served" (Ogunniyi, 2002b: 9).

In the following sections, the applicability of the Contiguity Learning Hypothesis to the present study is discussed in terms of the contexts under which the data was collected. Although the context of the interaction between the contiguous worldviews (i.e. traditional and school science) is regarded as a product of both physico-chemical

An examination of the above excerpt seems to illustrate Jegede and Aikenhead's (1999) claim that there is a relationship between *dependent collateral learning* and *hazardous border crossing*. The two subjects seem to have contrasted their traditional beliefs with the scientific ones encountered in the science class and then altered and reconstructed them under the influence of the new scientific knowledge. However, they transcended the border from one worldview to another in a *hazardous* way in the sense that their explanations ended up as alternative conceptions or misconceptions.

From Appendix 8, the results for Question 8 in the PAT (which is a question similar to the second story) seem to indicate that the border crossing into the science worldview with regards to this phenomenon was *hazardous*. Only a quarter of the subjects in E and C_2 answered the question correctly and got full marks. The rest either partly answered the question or gave wrong answers, thus revealing some alternative and/or misconceptions. For instance:

- S_{10}: *The energy of the electric saw was no longer at it normal*
- S_{11}: *His saw was not more powerful that at first it was now all and that lead to the delay that his foreman complained*
- S_{12}: *He meant that the saw was no longer able or it had no ability to do a fast job any more*
- S_{13}: *Babe Dlamini meant he has use more energy and the saw has no enough teeth*
- S_{14}: *It was not working faster and perfectly*
- S_{15}: *He meant that saw needs more energy because it is now old*

Some of the subjects' responses to this question seem to show that they had probably tried to alter their pre-conceptions under the influence of the newly encountered scientific explanation (a case of *dependent collateral learning*) but ended up with wrong explanations, thus exhibiting a *hazardous border crossing*. The latter could have been due to language problems such as using everyday words like powerful, job, newly encountered schema, or; (d) rejected and replaced by a newly constructed schema. In other words, learners reject or modify their original schema because it makes sense to do so.

Some subjects started off by explaining the phenomena using a traditional worldview and ended up using a scientific worldview after the intervention or after a discussion with others, thus revealing that they had undergone some sort of dependent collateral learning. The following examples from the responses to questions 2.2 and 2.3 in the PAT seem to illustrate this. One of the Swazi beliefs says that if one puts a coal in water that has been fetched after sunset, the one carrying it will be protected from the ghosts. One subject, S_8, mentioned this in her pre-test comment. However, her post-test comment revealed an attempt at explaining the phenomenon in a scientific way, which ended up with a misconception, showing that she was probably trying to alter her response by reconstructing the original schema under the influence of the newly encountered schema:

- *S_8 (Pre-Test): She would put a coal in the water*
- *S_8 (Post-test): Use little energy and do more work. She would use more energy and little work would be done*

Another subject, S_9, also started off with a traditional worldview at the pre-test stage and ended up with an alternative conception at the post-test stage as follows:

- *S_9 (Pre-test): She does not want to bring evil spirits into her home. Evil spirits would be in her home and there would be no peace*
- *S_9 (Post-test): It is because when the sun sets there will be more weight on the wheelbarrow. It would have took her a longer time to reach her destination*

satisfactory reason for holding on to traditional worldview and scientific worldview schemata even though the schemata may appear to conflict, or else he/she might have achieved a convergence toward commonality by one schema reinforcing the other, resulting in a new conception in the long-term memory. In the following excerpt from the videotaped discussion, the subject tried to hold on to both views even though he was aware of the conflict between them. He accepted the fact that the oil in Mr. Ngwenya's chain saw could have caused the saw's inefficiency, but also believed that a witchdoctors curse could have been responsible for it.

Langa: But as far as I am concerned, the fact that the oil was old also contributed to the efficiency of the machine. Although the oil was also old it means that the machine was working not in the right condition because it was consuming less oil, which is old, and also producing less work. Then on the other side of this tinyanga people, I will say that they ...with the working of the machine. This Inyanga, the Dlamini one, told Mr. Ngwenya that what he is going to see because he has insulted him, he has done wrong... He is going to see wonders which means his... his chain saw. I say that this got an effect because why then at the end it was the chain saw that got the problem?

Researcher: Do you think it is because of what the Inyanga said?

Langa: Yes. Yes. Why didn't Mr. Ngwenya become sick? Instead of him becoming sick, only the chain saw, as the Inyanga had said, becoming a problem. That is a problem...

Khosi: The problem is that Mr. Ngwenya did not service his chain saw.

Langa: How did the Inyanga knew that she was not servicing his chain saw, and in the end the chain saw was going to give him problems... Even though Mr. Ngwenya was drunk, he could have remembered the oil. But because of this inyanga's evil influence on him. He puts the spirits of forgetting on him. Mr. Ngwenya was thinking about the inyanga. The inyanga worked on Mr. Ngwenya... No the inyanga didn't work the machine; he worked Mr. Ngwenya so that he can't remember to service the machine.

When applying Jegede and Aikenhead's (1999) claim on the relationship between *secured collateral learning* and *managed border crossing* to the above excerpt, it seems as if Langa *managed* to cross the border between his traditional worldview and traditional worldviews and that of school science (in that they were able to correctly answer Q2.1), they however, continued to adhere to their traditional worldviews before and after the tests with regards to Q2.2 and 2.3. In other words, they were able to answer Q2.1 in order to achieve the social goal of passing the test (Aikenhead and Jegede, 1999) even though the knowledge presented seemed to contradict their traditional worldviews. This could also be viewed as an evidence of *parallel collateral learning* since the subjects' conflicting schemata seemed not to interact at all. They seemed to mobilize a particular worldview they thought was appropriate for the occasion. Actually, Jenkins (2000) has argued that oftentimes phrases that are not scientifically valid persist in everyday use even among so-called 'science specialists' in order to serve the purpose in hand.

From the foregoing, it is reasonable to conclude that the relationship between *parallel collateral learning* and *managed border crossing* seems to have been demonstrated. The subjects were able to manage the border into the science concepts taught while holding onto their traditional beliefs about the phenomenon oblivious of the conflict between them: a case of parallel collateral learning. However, it must be noted that the navigation from one worldview to the other has been *managed* and not *smooth* since the worldviews of the subjects and that of school are not congruent.

4.6.2.2 Secured Collateral Learning and Managed Border Crossing

In secured collateral learning, the conflicting schemata consciously interact and the conflict is resolved in some manner. In other words, the cognitive mechanism for conflict resolution in this model still remains unexplained (Ogunniyi, 1995, 2002a, 2002b). I shall elaborate on this later on. A person would have developed a fictitious stories because they could explain them using scientific concepts correctly. However, the post-test results for the PAT (Appendix 8) seem to reveal that although 83% of the subjects from both E and C_2 were able to locate the correct position for handling the wheelbarrow in Q2.1 (a question similar to the first story), almost all of their responses to Q2.2 and Q2.3 indicate that their traditional worldviews had not changed even after the intervention. Question 2.2 asked the subjects to explain why water should not be brought into a Swazi homestead after sunset. Question 2.3 required the subjects to describe what would happen if the rule of not bringing water into a homestead after sunset were broken. Three subjects (S_5, S_6, S_7) wrote the following reasons in the pre-test:

- *S_5: Because in old days they believe that the water can caused danger. There will be a storm or heavy rain accompanied by thunder and lightning*
- *S_6: She has the fear of spokes* (tipoko) because water must not enter home during spokes time. The water would be entered by evil spirits power which is not good*
- *S_7: Swazis tradition state that water must get to home before sunset. Her homestead might be struct by lightning*

By spokes*, subject S_2 means ghost (Spook). It is interesting to note that the above subjects wrote similar comments in the post-test:

- *S_5: Its superstition that when you bring water after sunset there will be heavy rains in your homestead. We believe that there will be rains in her homestead*
- *S_6: Her family believe in witchcraft. They think that water can be witched by spoke when the sun is not seen. The water was not going to enter the home*
- *S_7: It is because of the Swazi custom. Her homestead would be strucked by lightning.*

As can be seen from the above, the subjects responded using statements dealing with magic, mysticism, metaphysics, parapsychology, pseudo-science, and spiritism both at the pre- and post-test stages. These results seem to suggest that: although a considerable number of the subjects had *managed* to cross the border between their

The above relationships, however, raise a number of questions. For instance, how feasible is it to claim that a smooth border crossing is related to parallel or secured collateral learning, keeping in mind that such a transition occurs only for learners whose worldviews are congruent to that of school science? A better relationship would be that of smooth border crossing and no collateral learning. Also, how can hazardous border crossing be related to simultaneous collateral learning seeing that the latter requires a learner to fully understand a science concept in order to be able to apply it in other situations? If by impossible border crossing it were implied that a learner is unable to navigate the transition between his/her traditional worldview and the science worldview, would it then be possible to suggest that such a learner would revert to dependent collateral learning at a later stage?

Nonetheless, there seems to be logic in the relationships between: (1) managed border crossing and parallel or secured collateral learning; (2) hazardous border crossing and dependent collateral learning; and (3) impossible border crossing and no collateral learning. The following sections will discuss how applicable these relationships are to the subjects' traditional and scientific worldviews with respect to selected natural phenomena.

4.6.2.1 Parallel Collateral Learning And Managed Border Crossing

In the parallel collateral learning type, the conflicting schemata do not interact at all. The learners will use a scientific concept only in school, and never in their everyday world where commonsense concepts prevail. In section 4.6.1.1, it was shown that some subjects were able to *manage* the border crossing from a largely traditional worldview to a reasonably scientific one with regards to the phenomena cited in two variations in the degree to which the conflicting ideas interact with each other and the degree to which conflicts are resolved. He has identified four types of collateral learning, namely: parallel, secured, dependent and simultaneous collateral learning. These types are not separate categories, but points along a spectrum depicting degrees of interaction and resolution. The study considers only the first three because there was no evidence of the simultaneous type from the subjects' worldview presuppositions.

Aikenhead and Jegede (1999) have argued that collateral learning and border crossings are fundamentally interrelated because effective collateral learning in science classrooms will rely on successful cultural border crossings into school science. They have also claimed that the collateral learning theory is a cognitive explanation for the cultural phenomenon (conflicts between worldviews and cultures) mediated by transitions or border crossings between students' cultures and that of science. In a table summarizing the relationship between cultural border crossing, collateral learning and implications for teaching, Jegede and Aikenhead (1999) claim that there is a relationship between:

- Smooth border crossing and parallel, secured or no collateral learning.
- Managed border crossing and parallel, simultaneous, or secured collateral learning
- Hazardous border crossing and either dependent or simultaneous collateral learning
- Impossible border crossing and possibly dependent collateral learning, if at all.

regarding this phenomenon. Others gave reasons that were slightly different from the ones above. They said that touching the soil when a funeral was taking place hardened the soil. For example, in the pre-test this subject (S_4) said:

- *S_4: Traditionally, they say you do not work on the soil as proceedings at the funeral take place. People of her area would tell her they would do the same if one member of her family dies so that the soil is hard for those digging for the body.*

In the post-test, the subject said something similar to the above statement:

- *S_4: Traditionally they say the soil will be hard for those who are digging if a person in the same area is working on it. Some say they will also not help you when a member of your family dies. Nothing, but she would give the people a wrong picture in mind and would be charged a (inhlawulo) penalty by the indvuna of the area*

All these comments demonstrate vividly that there was no border crossing that took place regarding these beliefs. In other words, the subjects experienced an *impossible border crossing* into school science because of the traditional beliefs held by the community as well as possible consequences of violating such beliefs. Not only would the offender face the issue of symbolic and psychological violence (Tobin, 1996) but possible banishment by ostracism.

4.6.2 BORDER CROSSING AND THE COLLATERAL LEARNING THEORY

Jegede (1995) has proposed the Collateral learning Theory as a mechanism to explain how a learner harmonizes the conflict resulting from the contact between traditional worldview and that of science. He asserts that a non-western learner in a science classroom will construct scientific concepts side by side, and with minimal interference and interaction, with their indigenous concepts (related to the same physical event). As already detailed in Chapter 2, Jegede (1995) states that there are

The results based on questions 9.6 and 9.7 in the pre- and post-test in the PAT also demonstrated cases of *impossible border crossing* with regards to some traditional practices and customs prevalent in the subjects' socio-cultural environment. These questions required the learners to explain why a woman, la-Simelane, did not work in her fields when a funeral was taking place in her area. They were also asked to explain what they thought would happen to her if she went ahead and weeded her fields. The following are some of the comments in the pre-test made by three subjects (S_1, S_2, S_3):

- *S_1: It is because it is customed that don't toach soil when there is a funeral. There was going to have a hailstorm, which destroys the fields.*
- *S_2: It was because when there was funeral you must not dig the soil. There was going to be a lot of wind and rain*
- *S_3: It is she prevent thunder, storm and heavy wind. The maize will died because of heavy storm and heavy blowing wind.*

According to Marwick (1966), no work is done in the fields when a death has occurred in a Swazi village. The above comments seem to attest to that. The same subjects made similar comments even in the post-test:

- *S_1: It is because she believed that there would be the hailstorm. There would be the hailstorm which will destroy all the crops*
- *S_2: It is because when there is a funeral people were not allowed to hoe. There will going to have heavy rain and destroyed her field*
- *S_3: When there is a funeral touching soil is not allowed. They will be heavy storm that would destroy the plants*

The Swazi community in which the subjects lived believes that working in the fields when a funeral is taking place often results in hailstorms that destroy fields because the ancestors have been provoked. Some of the subjects expressed the same beliefs both in the pre-test and post-test. This showed their border crossing was *impossible* thought otherwise. The following argument from the videotaped discussion ensued between two subjects:

Sipho: I think it's because of the ancestors, because of Mr. Ngwenya's traditional medicine, his ancestor's medicine because they can work over a distance
Themba: How can they work like that?
Sipho: They work because they are spirits. They are all over.
Themba: Can you use evil spirits to something, which is a metal?
Sipho: Of course
Themba: Of course? Support
Sipho: Not exactly on that chain saw. The spirits affect Mr. Ngwenya the one that used the saw
Themba: I disagree. I think the problem was that Mr. Ngwenya did not change the fuels on chain saw that's why the chain saw was not in good order by that time he was using it. So, that's why it couldn't work properly.
Sipho: O.K. It might be Mr. Ngwenya didn't put the fuels because the evil spirits were working within him

From the foregoing, it seems as if Sipho strongly believes in evil spirits that can be conjured by ancestors for punishing human beings. He and a number of the subjects seemed to refuse to cross the border from their traditional worldview into the scientific worldview because they were of the opinion that in doing so they would lose their sense of identity as Swazis – a psychological state they seemed not ready to contemplate. Siphos' baffling last response to Themba's apparently scientific stance would defy the most carefully contrived empirical testability. Or else, how does one investigate the possibility of evil spirits influencing or working within Mr. Ngwenya? Duma's resolute commitment to his traditional belief as can be seen in the excerpt below illustrates this point further. His view supports that of Vusi in section 4.6.1.1 who also felt that his cultural beliefs gave him his identity as a Swazi.

Duma: This is our traditional belief
Vuli: O.K. which are your traditional beliefs?
Duma: My beliefs are in ancestors.
Vuli: How can you believe them and not in God? Do you see the ancestors?
Duma: Yes, yes like my grandparents. (Excerpt from videotaped discussion)

happened if she obeyed that instruction she must not bring water at night
(Excerpt from videotaped discussion)

The foregoing is a case of spiritism, which was earlier defined in section 4.3.3 as the belief that the spirits of the dead can communicate with, or manifest their presence to the living in various ways (The Webster Comprehensive Dictionary, 1995, p.1210). Challis, as cited in Marwick (1966), asserted that each Swazi family has its own ancestral spirits who are beings who bring good or bad luck and who need to be propitiated by sacrifice and constant flattery and attention. This, of course, depends on whether or not a family believes in such beings. According to Marwick (1966), these ancestral spirits can manifest their displeasure in several ways, some of which are the ones described in the above statements. According to Aikenhead's (1996) classification, these responses which are resistant to the scientific worldview seem to reveal that there has been an *impossible* border crossing, since the subjects are still holding onto their traditional worldview instead of crossing over to the scientific one. Their traditional worldviews and that of science are highly discordant causing the subjects to resist the latter. The fortress mentally maintained by the subjects (Ogunniyi, 1988) in the face of scientific evidence is what Jegede (1995) would have called "parallel collateral learning" or what Ogunniyi (1988) would have designated "harmonious dualism".

Secondly, some of the subjects' responses to story two (Appendix 5) seemed to also reveal that border crossing had probably not taken place in some of the subjects' minds as they continued to hold on to their traditional beliefs despite the exposure to science lessons. In other words, they had experienced an *impossible border crossing*. Some of them believed that evil spirits affected Mr. Ngwenya's saw while others find moving into the latter becomes virtually impossible. An incident recorded in the video discourse indicates that no border crossing had taken place in some of the subjects' minds. In other words, these subjects still held on to their traditional beliefs despite the fact that they had been exposed to science lessons that took their cultural beliefs into consideration. For these subjects border crossing seemed an impossible cognitive activity. Of course, it would be naïve to assume that the short instructional intervention would be sufficient to completely replace their traditional worldview with the scientific worldview.

It should be noted with respect to story one (Appendix 5) that some of the subjects believed that Zandile fell because of Botokoloshe and ancestral spirits. Botokoloshe are some traditional spirits that are believed to come in the form of an old dwarf with a very long beard. According to Garnett (1980) these legendary dwarfs dwell near rivers amongst boulders and reeds and can only be seen by children who have not reached the stage of puberty. The Swazis believe that enemies use these Botikoloshe as agents for witchcraft against a family or an individual. The Swazi society also believes that when a person dies, he/she automatically becomes an ancestral spirit, which would either bless or curse the family depending on whether or not the family adheres to certain rituals (Marwick, 1966). Some of the responses below illustrate this point quite vividly:

- *I think this botikoloshe contributed to the Zandile's fatigue The fact that his father told her...it meant that the father had experienced the khombos (bad luck)that were going to arise when you arrive with the water at night. So because her grandmother and also his father spoke almost the same thing it means there was a connection in the spilling of the water against the evil spirits, botikoloshe, which means the water was now having botikoloshe*
- *It was a punishment from the ancestors for her to have bring water at home at night, because I think it is a mistake ...this thing wouldn't have*

right time. Their discouraging them for doing work when it has grown dark not that the water was having botikoloshe

(Excerpt from videotaped discussion)

The discourse that took place in story two (Appendix 5), also revealed some alternative conceptions and/or misconceptions regarding the phenomenon. Some of the subjects expressed efficiency by combining the concepts of efficiency, i.e., work done over energy input instead of either expressing it in terms of energy input and output, or in terms of work put in and work put out. For instance:

- *The witchdoctor was not right; he had heard rumours. Mr. Ngwenya, as our teacher said he forgot to change the oil and the diesel. So the machine had maybe died or become tired. So it was unable to do work. What I can say is that in our Physics our teacher told us that efficiency is the work done over energy input. So the machine was doing less work than the energy put in due to petrol and diseals, which were not changed.*
- *I think the machine didn't do the work because he put more energy power but less work was produced. It was because the electrical saw was less efficient.*

(Excerpt from videotaped discussion)

From the above excerpts, it seems evident that the subjects had undergone a *hazardous* border crossing from their traditional worldview into that of school science. They seem not to want to appear stupid at school, and so are motivated to do as well as they can, but their weak academic ability tends to have limited their chances of success in school science.

4.6.1.3 Impossible Border Crossing

Impossible border crossing occurs when the learner's worldview and that of science are highly discordant causing learners to resist transitions from one worldview to the other. Learners, according to Aikenhead and Jegede (1999), experience a discordant cultural gap between their socio-cultural environment and school science and hence

In story one (Appendix 5), certain alternative conceptions emerged as the subjects attempted to explain the whole incidence in a scientific way. Some of the subjects brought in the concepts of work and force that had been covered in some of the science lessons but confused the concepts of work done with that of moments of a force. Some had alternative conceptions about power, confusing it with the concept of energy. For instance:

- *...As you know that force is equal to distance over work done she had to do the work, that is push the wheelbarrow, as she was nearer to the container there was a shot distance so to have the work done she had to apply more force so that the wheelbarrow could be pushed.*
- *...The girl lacked a lot of power. There was no power in her because she consumed a lot of energy playing netball at school and came back home...So she was very exhausted only to find that she was scared of her parents so she had to run to the river and in the running a lot of energy was consumed so the exhaustment was even double. Even looking at the position she was now carrying the wheelbarrow, the distance from where she was supposed to. She shortened the distance and I think that position was not a good position. The wheelbarrow was now heavy to her.*

(Excerpt from videotaped discussion)

The above responses seem to reveal that there was some *hazardous* border crossing whereby the subjects' traditional worldview and scientific worldviews are diverse, thus leading to a sort of hazardous transition. Further, the responses seem to suggest that the subjects attempted to cross the border between their traditional worldview to that of school science, but found it very difficult, and ended up producing some alternative conceptions and/or misconceptions. Also, some subjects used commonsense knowledge instead of the scientific knowledge they learnt in class. For example:

- *It was dark; she couldn't locate that hole that's why she fell.*
- *I don't think she fell because of the evil spirits, it was because she put her foot into a hole and she was very tired.*
- *That's not the case, Sihle. Its just parents wish to see their arriving at the*

(1998) recommendation for science educators "to separate ways of thinking and acting which are essential to the nature and practice of science from those which are cultural artefacts that may hinder science learning" (p.129). Vusi, on the other hand, seems to have resisted assimilation because he felt that he had to adhere to his cultural beliefs in order not to loose his identity as a Swazi. He, like the subjects in George's (1999b) study, clung to the traditional beliefs of his forebears despite the fact that he could not justify his viewpoint.

4.6.1.2 Hazardous Border Crossing

Hazardous border crossing occurs when the learner's worldview and scientific worldview are rather diffused leading to hazardous transitions from one worldview to the other. Aikenhead and Jegede (1999) have argued that the learners that attempt hazardous border crossings usually

> Do not want to look stupid at school, and so they are motivated to do as well as they can. They generally resist being assimilated into the culture of science, but their lack of academic savvy tends to limit their success at school science (p271).

Aikenhead (1996) suggests that the learners who undergo hazardous transitions pass a course without understanding the content. This poses little problems as long as the teacher does not "expect them to replace their commonsense conceptions with self-constructed knowledge or engage in scientific inquiry other than going through the motions of getting the right answer" (p18). Some of the subjects' responses to the different phenomena seemed to reveal some *hazardous* transitions in that their explanations are a mixture of scientific and alternative conceptions.

sometimes talk more lies. They will only give that if you come you will only give money to them, they don't want the customer to just live without having left some money to them and they want the customers to always believe what they say. There I disagree with everything.

Some of the subjects even went to the extent of arguing that education ought to change their cultural beliefs while others thought otherwise. The following excerpts from the videotaped group discussions illustrate this perspective graphically:

Thoko: I just like to tell you that we adopt these beliefs from our forefathers but that we have to come out from this thing. It will affect our future...
Vusi: We are Swazis
Thoko: Yes we are Swazis but we have to...
Vusi: We must, we must, we must.
Thoko: Now we are educated. Our forefathers were not educated that is why they believed that
Vusi: Does this mean that we have to change our cultural beliefs?
Thoko: No, we are not supposed to change our culture but we have to see something that is not true
Musa: No, but education doesn't change from our cultural beliefs. Education belongs to culture
Vusi: Belongs to it, how come? To culture? Culture and education?
Musa: The way you are educated can change your traditional beliefs.
Vusi: No
Musa: It can, it can
Vusi: No, no.
Musa: Anyway it can,
Vusi: But it's wrong. My friend it's wrong.
Musa: How?
Vusi: Because you know who you are... You must do your cultural beliefs at anytime if you want to do

From the above discourse one can draw the conclusion that Musa was somewhat assimilated to the scientific worldview regarding the phenomenon under discussion. His views are similar to those of the subjects in Waldrip and Taylor's (1999) study in which the subjects regarded the traditional beliefs found in their villages as outdated, and instead preferred the ones they acquired in their science lessons at school. Thoko, on the other hand, was of the opinion that they had to exercise discretion on what to believe and what not to believe. Her statement is in line with Allen and Crowley's the subjects can be considered to have made spirited attempts at moving from a worldview they held before instruction to that of school science. Had the worldviews been congruent to that of science, the border crossing would have been described as smooth.

Aikenhead and Jegede (1999) argue that:

> When the culture of science is generally at odds with a student's life-world, science instruction will tend to disrupt the student's worldview by trying to force that student to abandon or marginalize his or her life-world concepts and reconstruct in their place new (scientific) ways of conceptualization (p274).

Aikenhead and Jegede (1999) regard this instructional approach a form of assimilation in that it attempts to subjugate the learner's worldview to that of science. It seemed evident that some of the subjects had undergone some kind of assimilation and had actually turned against the traditional beliefs prevalent in their communities. These students even referred to their own indigenous beliefs as superstitions. The following excerpts from the videotaped group discussions illustrate this point quite succinctly:

- *I think Zandile's grandmother believed in superstitions...When the water is fetched after sunset there is no evil spirits botikoloshe in the water. Its just superstition*
- *...Her grandmother she wasn't correct. Evil spirit it depends that she believed on them but I don't think they are there because those ancestors died very long time ago so someone who is dead cannot do anything because he is not on earth so I don't believe*
- *...As for the spirits I don't believe that they are there, how can someone who died long ago come on earth, so I disagree with Zandile's grandmother.*
- *Mr. Ngwenya, he only knew that he has to go to work and that his machine was not in a good condition. He was supposed to check each and every time when he was about to go to work. That is what makes it to not work properly, the machine. And this inyanga evils, I want to disagree with him because each and every time when they talk, they talk as if they are peoples who knows everything yet they are people who*

largely traditional worldview perspective to that of science which they encounter in their science lessons in order to come up with what can be regarded as reasonably scientific explanations.

The second story deals with a man who had an inefficient electric saw (Appendix 5). Some of the subjects' responses also seemed to reveal that border crossing had been somewhat *managed*. The subjects tried to explain the phenomenon using a scientific viewpoint based on what they had learned in the science classrooms. They tried to explain the incidence using the concept of efficiency, which compares the useful work achieved with the work put in over the same length of time (Byron, 1992). Efficiency can also be expressed in terms of useful energy output and total energy input, or in terms of useful power output and total power input. The following are some of the subjects' responses from the videotaped group discussion:

- *Mr. Ngwenya does not service his saw. It proves that the oil there was not oil but very old like the tank. So as he continued using it, it lessened the efficiency of the saw because it was not renewed...the saw was now lacking power to do the work. There was no energy transferred from the oil to the saw.*
- *...I don't agree about the witch doctor told him because when something is less efficient it uses a lot of energy to produce something less. I think the saw was now in its abnormal state so it was not its normal so while using it Mr. Ngwenya while he was using it, it take a long time to do less work. So the inyanga is not telling us the truth about what happened to Mr. Ngwenya and the other man who were fighting because of that they were drunken... The saw was less efficient. Full stop.*
- *I think the electrical saw cut not many trees just because he had thought of not changing ...That's why Mr. Ngwenya put more effort but it produced less work. The inyanga was not true by telling Mr. Ngwenya that it was caused by his opponent whom they were fighting with in the shebeen for this electrical saw not to do more work. It was just because it had faults it needs its fuel to be changed to go back to its normal*

From the foregoing, there seems to be considerable evidence of *managed* border crossing though sometimes expressed in an incoherent way. There is a sense in which

The first story is about a girl who fell while pushing a wheelbarrow containing water containers (Appendix 5). Some of the subjects were able to explain the situation using the principle of moment's concept, which states that the sum of the clockwise moments is equal to the anti-clockwise moments. In this case, they had to realize that the position at which Zandile held the wheelbarrow had a great effect on the way she pushed the water home. Some of them even brought in the concepts of energy and power. The following excerpts from the videotaped group discussions are representative:

- *My friend, O.K. What does the principle of moments say? They say when an object is in equilibrium its sum of anticlockwise moments is equal to... Let's say Zandile held the wheelbarrow closer to the equilibrium, so that's why it was heavy. Then she used more energy when going than the work she did. She used more energy than what she was supposed to use... Then she ran which meant more energy was used. I think that is why she was lacking energy.*
- *The reason why she came late with the water at home is because the position, which she was holding the wheelbarrow, is not the right position she was supposed to hold when pushing the water home...If she was holding the wheelbarrow in that position she was making herself to work more than the power needed by the wheelbarrow. ...*
- *You can say much energy was consumed when she was playing netball at school, so the energy she need when pushing the wheelbarrow with the water and it was in the wrong position. The distance from the pivot is short. So in order for her to push to consume less energy the distance must be a little bit long so that she must increase the distance so that little energy is consumed is continue pushing the wheelbarrow.*
- *The other reason is that she handled the wheelbarrow on the wrong place she held it too close, hence she had to put more force therefore she lost a lot if energy and became tired.*

The above excerpts can be regarded as examples of *managed border crossing* from a traditional worldview into a scientific one. The subjects' worldviews were classified earlier on using the "My Idea About Nature" (MIAN) questionnaire as largely traditional. This means that the subjects had to *manage border crossing* from a designated by Phelan et al.'s (1991) in terms of: "other kids", "smart kids", and so forth. First, this is because this is beyond the scope of the study and secondly, it is a type of classification requiring a much longer observation of learners in class and outside class activities. Besides a student categorized today as "I Don't Know" might as a result of a significant event or experience change his/her attitude and later become a "Potential Scientist". In this study border crossing was construed to have taken place if a subject showed a paradigmatic shift as a result of the instructional intervention between the pre-and post-test as measured by the PAT after the post-test. Also, in the study, only the last three types of border crossing (i.e. managed, hazardous and impossible) actually observed were considered for analysis since none of the subjects demonstrated smooth border crossing – i.e., their worldviews were not congruent with that of school science.

4.6.1.1 Managed Border Crossing

Managed border crossing occurs when the learner's worldview is different from the science worldview thus requiring the transition from one to the other to be managed. According to Aikenhead and Jegede (1999), the way such a learner acquires this foreign content makes it accessible to him/her whenever he/she needs to achieve such social goals as talking with his/her teacher or passing examinations, even though that knowledge may contradict or seem irrelevant to his/her traditional worldview. According to Aikenhead (1996) such a learner sees science courses as more fact-oriented and memorization-oriented than other non-science classes. Some of the subjects' responses in this study seemed to reveal that they had somewhat *managed* some border crossing as they tried to explain the two phenomena presented in the two stories in a scientific way based on what they had learned in the science classrooms.

instructional intervention, to debate amongst themselves their views on certain phenomena. Their discussions, which were video recorded, are considered in the subsequent sections. All of the subjects who participated in the discussion had been exposed to scientific and traditional worldviews through their interaction with a traditional community and through the science lessons that had been taught before the group discussion. The aim was to test whether or not the subjects' views on certain issues had shifted from a traditional worldview to a scientific worldview as a result of the intervention. They were expected to answer the question posed to them in order to demonstrate whether or not border crossing might have taken place in their learning, that is, if they had been able to cross from a traditional worldview to a scientific worldview. Two stories based on prevalent traditional beliefs were narrated to the subjects by the researcher at the end of which questions were asked that gave the subjects the opportunity to express their views freely (see Appendix 5).

4.6.1 BORDER CROSSING

As mentioned in chapter two, Aikenhead (1996) considers a learner's experiences with school science in terms of "crossing borders" from the sub-cultures associated with the learner's socio-cultural environments into the sub-cultures of science. To acquire the culture of science, a subject is expected to shift intellectually from his/her everyday life-world perspective with its traditional worldview presuppositions and commonsensical understanding to that of school science, a process that might obviously result in conflicts. Aikenhead (1996) adopted four types of border crossing between the learner's traditional worldview and that of school science depicted by Phelan et al. (1991), namely: smooth, managed, hazardous, and impossible. However, this study adopted the types of border crossing without using the other categorizations interest in science does, to some extent, have an influence in their conception of force, energy, work and power.

A lot of literature has indicated that the performance of non-western learners in school science is sometimes hampered by their traditional worldviews and/or their commonsensical knowledge (e.g. Kawagley et al, 1998; Gunstone and White, 2000; Fairbrother, 2000). The next section explores some of the theories/hypotheses that have been posited to explain the learning of science in traditional or indigenous societies.

4.6 BORDER CROSSING, THE COLLATERAL THEORY, AND THE CONTIGUITY HYPOTHESIS

This section attempts to answer the following research question: How applicable are three cognitive theories/hypotheses (i.e. Border crossing, Collaterality and Contiguity) to the subjects' traditional and scientific worldviews with respect to selected natural phenomena? The aim of this section is to ascertain whether or not Aikenhead's (1996) Border Crossing Theory, Jegede's (1995) Collateral Learning Theory and Ogunniyi's (1995) Contiguity Hypothesis are explicable to the subjects' cognitive border crossing into school science. These subjects underwent an instructional intervention that used concept mapping and took into consideration their traditional worldviews. The section begins with a description of examples of border crossing from a traditional worldview to a scientific worldview that were identified in the PAT and the subjects' discourse during a videotaped group discussion.

A group of twenty subjects from groups E and C_2 were asked at the end of the by the subjects in C_1. The subjects in E got the lowest mean score. The low interest group in C_2 got the highest mean, followed by the group in E, with the group in C_1 coming last. The results of this group of subjects seem to indicate that the intervention had a positive effect on the learning of the topic on force, energy, work and power.

Table 9: Performance on the PAT According to Interest In Science For Each Group on the Concepts of Force, Energy, Work and Power

Test	Group	Interest in science	N	Mean	S.D	t-value
Pre-test	E	H	45	9.42	4.67	**0.648**
		L	6	8.08	4.77	
	C_1	H	31	10.87	4.30	**2.41***
		L	14	8.46	2.83	
Post-test	E	H	45	19.91	6.91	**0.0619**
		L	6	19.8	3.55	
	C_1	H	31	20.67	6.45	**6.3***
		L	14	12.5	3.17	
	C_2	H	24	27.44	6.98	**1.843***
		L	7	21.57	7.55	

*** Statistical significance at p = 0.05**

A t-value of 0.648 in the pre-test and t-value of 0.0619 in the post-test at a 0.05 level of significance showed that there was no significance difference in the performances of the high and low interest learners in E in both tests. A t-value of 2.41 in the pre-test and a t-value of 6.3 in the post-test at a 0.05 level of significance showed that the difference between the performances of the high and low interest learners in C_1 was statistically significant in both tests. A t-value of 1.843 at a 0.05 level of significance showed that there was a statistically significant difference in the performances of the high and low interest learners in C_2. The results seem to suggest that the subjects' exception of the seventeen and nineteen year olds where E had the least mean, the subjects in E and C_2 performed better than those in group C_1.

Table 8: Analysis Of Variance Of Pre-Test And Post-Test Scores According To Age on the PAT

Group	Test	Source	Df	SS	MS	F
E	Pre-test	Between	4	101.31	25.33	1.112
		Within	46	1047.32	22.77	
	Post-test	Between	4	268.73	67.18	1.064
		Within	46	2903.43	63.12	
C_1	Pre-test	Between	4	51.51	12.88	0.691
		Within	41	764.47	18.65	
	Post-test	Between	4	285.79	71.45	1.46
		Within	41	2010.8	49.04	
C_2	Pre-test	Between	-	-	-	-
		Within	-	-	-	
	Post-test	Between	4	253.81	63.45	1.391
		Within	26	1186.13	45.62	

*** Indicates statistical significance at p = 0.05**

As can be seen in Table 8, all the F-values for the three groups revealed that there were no significant differences between the performances of the age groups in both the pre-test and post-test at a 0.05 level of significance. This suggests that age does not have a significant influence on the subjects' performance on the topic of force, energy, work and power.

4.5.3 The Effect Of Interest In Science On The Subjects' Understanding Of Force, Energy, Work And Power

An examination of Table 9 shows that the subjects that have a high interest in science performed better than those with a low interest in both the PAT pre-test and post-test. The subjects with a high interest in science in C_2 got the highest mean score, followed

Table 7: Performance on the PAT According To Age per group on the Concepts of Force, Energy, Work and Power

Age	Test	Frequency			Mean			S.D		
		E_1	C_1	C_2	E_1	C_1	C_2	E_1	C_1	C_2
<17y	Pre	12	15	-	10.92	10.43	-	4.14	4.92	-
	Post	12	15	8	22.42	18.21	30.00	7.38	7.21	8.64
17y	Pre	14	6	-	7.64	9.30	-	4.18	3.95	-
	Post	14	6	8	18.31	19.50	27.75	4.46	6.72	6.92
18y	Pre	15	12	-	9.67	9.67	-	6.02	4.31	-
	Post	15	12	7	19.89	14.71	23.21	6.62	6.04	5.34
19y	Pre	7	7	-	8.58	11.50	-	2.48	3.25	-
	Post	7	7	5	18.42	22.36	22.30	7.53	5.46	5.12
>19y	Pre	3	5	-	9.50	9.50	-	3.97	2.17	-
	Post	3	5	3	19.67	17.58	24.50	11.01	6.64	10.83

seventeen year olds got the lowest. The under-seventeen, seventeen and nineteen year olds in C_1 had higher mean scores than those in E. The eighteen and above nineteen year olds in E each had the same mean scores as of those in C_1.

The post-test results show that the under-seventeen year olds in E got the highest mean while the seventeen year olds got the lowest mean in the group. The nineteen-year olds in C_1 got the highest mean while the seventeen year olds got the lowest. The under-seventeen year olds in C_2 got the highest mean while the nineteen year olds got the lowest.

Almost all the age groups in C_2, with the exception of the nineteen year olds in C_1, outperformed their age mates in the other two groups. In all the age groups, with the

The results of the post-test also show that the males in C_2 out-performed the males in the other two groups. The males in C_1 followed those in C_2 and the males in E came last. The results also show that the males in C_2 benefited more from the intervention than their counterparts in E. Likewise the females in C_2 came first in the post-test, followed by the females in E, and lastly females in C_1. The performances of the females show that the intervention had a positive effect on the learning of the topic on Force, energy, work and power in both groups E and C_2. With one exception of E at the pre-test and C2 at the post-test the males consistently outperformed their female counterparts. This corroborates the findings in earlier studies (e.g. Chambers and Andre, 1997; Greenfield, 1996; Catsambis, 1995)

A t-value of 1.69 for group E and a t-value of 4.61 for group C_1 at a 0.05 level of significance, reveal a statistically significant difference between the performances of the gender groups. A t-value of 0.63 at a 0.05 level of significance for group C_2 shows that the difference in the performances of the males and females was not statistically significant. These results seem to suggest that gender does seem to predispose the subjects to learn the concepts of Force, Energy, Work and Power regardless of the teaching method used.

4.5.2 The Effect Of Age On The Subjects' Understanding Of Force, Energy, Work And Power

An examination of Table 7 reveals that the under-seventeen year olds in E got the highest mean on PAT while the seventeen year olds got the lowest mean in the group in the pre-test. The nineteen year olds in group C_1 got the highest mean while the

Table 6: Performance on the PAT According To Gender Per Group on the Concepts of Force, Energy, Work and Power

Test	Group	Gender	N	Mean	S.D	t-value
Pre-test	**E**	**M**	**26**	**9.92**	**5.59**	**0.953)**
		F	**24**	**8.71**	**3.49**	
	C_1	**M**	**21**	**11.55**	**4.25**	**2.307***
		F	**25**	**8.89**	**3.49**	
Post-test	**E**	**M**	**26**	**21.38**	**6.51**	**1.69***
		F	**24**	**18.28**	**6.47**	
	C_1	**M**	**21**	**22.17**	**6.81**	**4.61***
		F	**25**	**14.38**	**4.02**	
	C_2	**M**	**19**	**27.34**	**7.90**	**0.63**
		F	**12**	**26.11**	**3.54**	

*** Statistical significance at p = 0.05**

25 females who obtained a mean and standard deviation of 8.89 and 3.45, respectively.

An examination of the post-test results shows that the males got higher means than females in all three groups. The 26 males in E had a higher mean of 21.38 than the 24 females who got a mean of 18.38. The males had a standard deviation of 6.51 while the females' was 6.47. The 21 males in C_1 got a higher mean of 22.17 and a standard deviation of 6.81 as compared to the 25 females who got a mean of 14.38 with a standard deviation of 4.02. The 19 males in C_2 also outperformed the females. The mean score for the males was 27.34 with a standard deviation of 7.90. The 12 females got a mean of 26.11 and a standard deviation of 3.54.

the wind might hit and maybe bend the umbrella

Once again, the subjects' responses seem to reveal some conceptual and linguistic problems. They could not identify, explain the concept of air resistance or friction and its application to an everyday life situation. Their linguistic problems emanating here can be associated with second language learners (Duran, Dugan and Weffer, 1998; Rollnick and Rutherford, 1996)

4.5 DEMOGRAPHIC EFFECTS ON THE SUBJECTS' CONCEPTIONS ON SELECTED NATURAL PHENOMENA

This section attempts to answer the following research question: Do certain demographic factors such as sex, age group, and interest in science influence the students' traditional and scientific worldviews on the selected practices found in their socio-cultural environment?

4.5.1 The Effect Of Gender On The Subjects' Understanding Of Force, Energy, Work And Power

As can be seen in Table 6 below, an analysis of the pre-test data on PAT gathered from E shows that even though the 26 males in group E got a higher mean of 9.92 with a standard deviation of 5.59 than the 24 females who got a mean and standard deviation of 8.71 and 3.49, respectively, a t-value of 0.953 at a 0.05 level of significance suggests that there was no statistical significance between them. On the other hand, a t-value of 2.307 at a 0.05 level of significance revealed that there was a statistical difference between the pre-test mean scores of the 21 males in group C_1 who got a higher mean of 11.55 and a standard deviation of 4.25 as compared to the power used by the oxen and got full marks. 44% of the subjects in E, 36% in C_1, and only 16% in C_2 got zero for the question. The rest of the learners answered the question partially. They did not convert the minutes to seconds.

Question 11 required the learners to use their knowledge of friction to explain the effect of air resistance against Zodwa's umbrella as she was running through the rain and wind. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception of science concepts and principles and the application thereof. The mean percentages for E and C_1 were less than 50%. 53% of the subjects in C_1, 48% in E, and 42% in C_1 did not mention friction as the cause for Zodwa's slack speed. Those who did were 52% of the subjects in C_2, 40% in C_1, and 35% in E. The learners' responses either showed some misconceptions or some common sense knowledge. The following are some of their responses:

- *This is because there is more gravitational force acting in the umbrella*
- *Zodwa prevent hitting with Thandi while they are running together*
- *Drops of mud splashes when running*
- *There is a pressure towards Zodwa's direction the wind which blows against Zodwa*
- *She knows she has an umbrella, she did not want to share the umbrella with Thandi*
- *I think it is that Zodwa uses her energy on the umbrella and when running but Thandi uses it for running only*
- *It is because Zodwa is carrying an umbrella which prevents her from becoming wet and the umbrella has got weight which prevents her from running faster than Thandi who is carrying nothing*
- *Zodwa is not catched by the rain because she's got an umbrella but Thandi is running faster because she doesn't have an umbrella*
- *She is doing some work by running and she is doing work by applying force to an umbrella*
- *The force and power because Zodwa has applied force and power*
- *It is the force converted by the umbrrella*
- *Zodwa doesn't want her umbrella to be broken by the wind*
- *I think that Zodwa understands that if she runs with the umbrella in her hand,*

four fifths (87% - 94%) of the subjects in E and C_2 got zero marks for the question. Questions 9.6 and 9.7 tested the subjects' alternative worldviews regarding some traditional beliefs and customs prevalent in their socio-cultural environment. The results are discussed in a later section.

Question 10, consisting of two sub-sections, is about two boys, Jabulane and Vusi, who used their father's span of oxen to pull a load of firewood from a forest that is one km away from their homestead. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception of scientific concepts and principles, application of scientific knowledge and the use of process skills. Q10.1 required the subjects to use their knowledge of the concept of work to calculate the amount of work done by a span of oxen when pulling the load of wood. The mean percentages were above 50% for all the groups. About seven tenths (68%) of the subjects in C_2, about two fifths (38% - 47%) in C_1 and E were able to calculate the work done by the oxen in pulling a load of firewood. On the other hand, 29% of the subjects in E, 16% in C_1 and 10% in C_2 could not calculate the work done by the oxen and got a zero mark for the question. The rest of the learners used the correct formula but did not convert the units for the distance from kilometres to metres.

In Q10.2, the subjects were supposed to use their knowledge of the concept of power to calculate the amount of power used by the oxen to pull a load of wood from the forest to Jabulane and Vusi's home. The results yielded mean percentages that were less than 50% for E and C_1. Slightly more than half (55%) of the subjects in C_2, about a fifth (16%) in C_1 and about a tenth (8%) in E successfully calculated the amount of could not answer Q9.1 and so got a zero mark.

The mean percentages for Q9.2 range from 49% to 55%. About two fifths (42%) of the subjects in E, about a third (35%) in C_2, and a about a fifth (18%) in C_1 could give a correct description of the hoe's energy at point B while about a third (31% - 35%) in C_2 and E, and a fifth in C_1 could not. In Q9.3, the mean percentages for E and C_2 are below 50%. None of the subjects in C_1 and C_2, and only 4% in E could fully describe the energy of the hoe at point C. About four fifths (82%) of the subjects in C_1, and slightly less than half (46% - 48%) in C_2 and E got zero scores for the question.

Q9.4, the fourth sub-question, required the subjects to calculate the energy gained by a hoe at its highest point in the air when raised by a woman hoeing here fields. The results show that the subjects in C_2 got the highest mean of 1.29 with a mean percentage of more than 50%. The subjects in E got a mean score of 0.92 while those in C_1 got 0.81 with mean percentages that were less than 50%. About two fifths (38% - 48%)of the subjects in C_2 and E, and a fifth in C_1 obtained the full marks for this question. E had the highest number of subjects (44%) who could not calculate the energy gained by la-Simelane's hoe at point A, and got zero marks. 38% of the subjects in C_1 got zero while only 19% in C_2 got zero.

In Q9.5, the students had to calculate the speed with which the hoe hit the ground each time the woman brought it down while hoeing in her fields. All the subjects from C_1 got a zero mark. The subjects in C_2 and E got mean percentages of less than 50%. Only a tenth of the subjects in C_2, and about one twentieth (4%) in E were able to calculate the speed of la-Simelane's hoe each time it hit the ground. More than learners' responses that revealed some alternative conceptions or commonsense knowledge:

- *He meant the was nothing for him to do with fast or being slow but only the machine being in good condition would determine*
- *His electric saw was no longer new. It was no longer working as the time it was new*
- *He was meaning his saw cannot cut many logs at very high speed he was not in good condition*
- *He meant that the saw was no longer able or it had no ability to do a fast job any more*

The above excerpts suggest that the learners had not fully understood the concept of efficiency enough to apply it to everyday life situations. Some of the statements also reveal some linguistic problems associated with second language learners (Rollnick, 2000; Rollnick and Rutherford, 1996) in terms of sentence construction, tenses, spelling, everyday meanings and so forth. For example, the subjects use the words "job" and "work" interchangeably. The word "work" has different meanings in everyday use and in science. In science it is defined as the force applied over a given distance.

Question 9, consisting of seven sub-sections, is about a woman, la-Simelane, who was hoeing her maize fields using a 20N hoe. This question expects that the subjects would use at least one or two of the assessment framework categories such as: the use of process skills, the conception and application of scientific concepts and principles. The first three sub-questions required the subjects to describe the types of energies undergone by a hoe at three different points as a woman hoeing her fields raised it up and down. In Q9.1, the mean percentages were less than 50% for C_1 and C_2. About a third (29% - 30%) of the subjects in E and C_2, and about a fifth (18%) in C_1 could correctly describe the energy of the hoe at point A. The same proportions of subjects the energy types or conversions.

In Q7.2, all the groups had mean percentages that were more than 50%. Only slightly less than a tenth (i.e., 6% - 7%) of the subjects could fully describe either the energy conversions or energy types that took place in the coal fire. Most of the subjects either gave a partial answer or failed to answer the question. In Q7.3, the mean percentages were all less than 50%. None of the subjects from the three groups were able to fully describe the types of energies or energy conversions that were taking place in the lighted candle. In Q7.4, the mean percentages for all the groups were more than 50%, and more than four-fifths of the subjects could name the energy changes that were taking place in the broom as Duduzile was moving it back and forth when sweeping the floor.

In Question 8, the subjects were told a short story of a man, Babe Dlamini, who had been accused by his foreman of being slow in his job of cutting down trees using an electric saw. The man had defended himself by saying that his saw was no longer 100% efficient. The subjects were then asked to explain what Babe Dlamini meant by this. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception of scientific concept and principles, and their application to explain their viewpoints. The mean percentages for E and C_1 were below 50%. About a quarter of the subjects in E and C_2, and none in C_1 were able to explain the concept of efficiency. More than nine tenths (96%) of the subjects in C_1, about a third (35%) in E and a quarter in C_2 got a zero mark for the question. The rest of the learners gave partial explanations. Here are some of the

- *It was because he has applied more force as he is to heavy and the rough concrete made it difficult*
- *The potential energy was strong*
- *The weights are too high for him to push them because of his weight*
- *He don't have enough power*

The foregoing seems to reveal that the subjects have conceptual problems in that they could not identify the concept of friction. Instead, they used other irrelevant concepts such as potential energy and power. They also seemed unable to see the link between the concept of friction and the concepts of weight and force of gravity. This further demonstrates their inability to apply concepts learned in class to everyday life situations (Solomon, 1987).

In Q6.2, the subjects had to calculate the acceleration of a block as it was pushed along a rough surface. The results show that none of the groups got a mean percentage that was higher than 50%. Only 45% of the subjects in C_2, 33% in E, and 18% in C_1, could calculate the acceleration of the block that was pushed by Mr. Zwane. 73% of the subjects in C_1, 54% in E, and 48% in C_2 got a zero mark.

For questions 7, the subjects were supposed to use their knowledge of energy conversions to describe the energy changes taking place in a candle-lit kitchen, which consisted of an old woman sitting in front of a coal fire and a girl sweeping the floor. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception of science concepts and principles and the application thereof. In Q7.1, the mean percentages for all three groups were above 50%. More than two thirds of the subjects were able to describe the energy types or conversions taking place in Gogo Shongwe as she was sitting in front of the fire. About a third of the subjects in C_1, and about a fifth in E and C_2, could not describe

Again the above excerpts reveal that the subjects have conceptual, procedural and linguistic problems as will be encountered in most items. The critical terms such as limit of elasticity, limit of proportionality, extension, and so forth have turned to be what Ogunniyi and Fakudze (2002) called:

> …alien and inaccessible to these students. All they do is to mutter these concepts like an incantation through which they seek to conceal their own ideas and doubts, and hoping somehow that the words themselves would work of their own accord whether understood or not (p.11).

According to Jegede and Okebukola (1991a), another possible explanation for this could be that the students with a high level of belief in African traditional cosmology, superstitions and taboos tend to perform poorly in scientific process skills such as observation, interpretation of data.

Question 6, consisting of two sub-questions, deals with Mr. Zwane, a hefty man who had difficulty pushing a 10kg block. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception of scientific concepts and principles as well as the use and application of process skills. In Q6.1, the subjects were supposed to explain why Mr. Zwane could not make the 10kg block he was pushing to gain a higher acceleration. The results show that all the groups got mean percentages that were less than 50% and less than half of the subjects in all three groups were able to mention friction in their responses. More than half gave other wrong reasons for the low acceleration and some of their alternative conceptions were as follows:

- *I think it is because force of gravity push down block which cause it to move slower*
- *It is caused by the lack of force*

What can be gleaned from the list above is the subjects' attempt to describe the use of catapults in killing birds. Their intuitive responses are in terms of their own experiences with properties of good catapults. They seem to be bogged down with descriptions of the phenomenon instead of realizing the application of the relevant scientific concepts and principles.

In Q5.2, the subjects had to interpret a graph representing the change in the length of a catapult against the forces used to stretch it. They had to be able to tell if it obeyed Hook's law or not. The results show that the subjects in C_2 and E got a mean percentage less than 50%. About a third of the subjects in C_1 and E, and a quarter in C_2 could interpret the graph correctly. They all explained that the graph did not show that the extension of the catapult was directly proportional to the force applied on it, and that there was no limit of proportionality on the graph. A few of the subjects got one mark for saying that the graph did not obey Hook's law but could not explain the reason for this. Those subjects who left out the limit of proportionality got one and a half marks. Some did not attempt the question at all. These results corroborate Beaumont-Walters and Soyibo (2001) findings in which the subjects of their study had mean scores that were low and unsatisfactory with regards to science process skills such as interpreting data. The following are some of the subjects' responses:

- *No because an object when it is moving it starts from a resting point, then constant*
- *Yes, because he did not stretch the catapult beyond its limit of elasticity*
- *Yes, because Mandla's catapult had a limit of proportionality*
- *Yes, because the length of the extension increased when a force was applied*
- *Yes, because it did not get into its normal length after stretching it*
- *Yes, because the catapult then increases*
- *He did not obey the law because when the extension go to rest it reduces force*

Question 5, divided into subsections, is about Mandla and his friends who brought the catapults they used for killing birds to school. This question expects that the subjects would use the process skills category of the assessment framework. Q5.1 tested the subjects' ability to design an experiment showing how the elasticity of a catapult varied with force. The results show that only the subjects in C_2 got a mean of 2.02 with a mean percentage that was higher than 50%. The subjects in E and C_1 each got a mean score of 0.50 with a mean percentage that is lower than 50%. Only about a tenth of the subjects in C_2 and almost three-quarters in the other two groups could not sketch the graph and got zero marks. None of the subjects from all three groups got full marks. The highest score obtained was 3 out of 4 and was obtained by almost two fifths of the subjects in C_2, and a tenth in C_1 and E. These are some of the subjects' responses:

- *They first applied a small amount of force then more, then small, then more it was a vice versa.*
- *They apply force by stretching back and the force of extension is applied energy is released*
- *They hold the catapults and apply different force to the catapults. More energy will cause the catapult to move a long distance than less force applied*
- *They first put a small stone on their catapults and then they stretch them with more force so that it can go to a far distance.*
- *They first put a stone on the leather part. They then hold the wooden part. Lastly they hold the stone and pull the elastic and the catapult were stretched.*
- *They stretch the catapults with a stone in it. Then the release the stone by allowing the belts to retain their normal positions*
- *Firstly, the put a small stone on the catapults and they stretch it horizontally. The angle between the handle and the catapults was 90°.*
- *Mandla has to take a pebble and put it on his catapult. He has to apply force. He has to remove his hand and he will get a bird if possible*
- *Mandla handled the catapult with one of his hands and he pulled the catapult with his potential energy and the catapult remain stretched with potential energy.*
- *They bind the stone with the catapult then they stretch when they stretch the stone will loose to the spring and thrown away with power*

everyday life contexts. They tended to use irrelevant concepts such as acceleration, power, work, and centrifugal force in place of distance, effort or force.

Question 4, divided into four sub-sections, is about Mr. Mtsetfwa who drove his front wheel drive from Mbukwane to Nhlangano. This question expects that the subjects would use the process skills category in the assessment framework. Q4.1 required the learners to calculate the mass of Mr. Mtsetfwa's car. The results reveal that the mean percentage for C_2 was higher than 50% while the mean percentages of E and C_1 were lower. About half of the subjects in C_2 could calculate the mass of Mr. Mtseftwa's car, while only a fifth could do so in C_1 and E. In Q4.2 the subjects had to calculate the resultant force driving Mr. Mtsetfwa's car forward. The results reveal that the mean percentages for all the groups were very low and less than 50%. About three fifths of the subjects in E and C_2, and about two fifths in C_1 got a zero mark. Only about a third of the subjects from C_2, a tenth in E and a twentieth in C_1 could calculate the resultant force that drove Mr. Mtsefwa's car forward.

In Q4.3 the subjects had to calculate the acceleration of the car. The results show that the mean percentages for all the groups are less than 50%. Only a few of the subjects could calculate the resultant force successfully, and got full marks. More than four fifths of the subjects got a zero mark. Q4.4 tested the subjects' ability to sketch a velocity-time graph describing the movement of a car against time. The results show that the mean percentages of all the groups are less than 50%. About a tenth of the subjects in C_1 and C_2, and 2% in E, were able to sketch the graph correctly. Some of the subjects either drew a smooth curve that started from the origin or left out the horizontal line at the beginning of the graph and got half a mark

There were more subjects who could not use the principle of moments in E (81%) and got zero than in the other two groups, where there were about a half of them.

Q3.7 required the subjects to apply their knowledge of principle of moments in an everyday life situation where they had to suggest two ways that Sipho could have used to open a tin lid. The results show that only the subjects in C_2 got a mean percentage that was above 50%: the other groups got less. Only about a fifth of the subjects in all the three groups were able to give two correct suggestions of how Sipho could open the lid of the paint tin such as:

- *Increase the distance from the pivot to the effort where the force is applied. Increase the force applied to the screwdriver*
- *He could have increased or applied more effort. He could have also used another long screwdriver*
- *Look for a longer screwdriver. Add the effort.*

Half of the subjects in C_1, about two fifths in E, and one-twentieth in C_2 failed to give concrete suggestions and got a zero mark. The rest could only give one correct suggestion for opening the tin. Some of the responses are as follows:

- *Increase energy and his work*
- *Sipho will add more energy. Sipho will try other screwdrivers*
- *He must push the screwdriver at least more than 1 cm under the lid*
- *He must increase the acceleration*
- *Decrease the force on the other side*
- *The size of the screwdriver must be increased*
- *He could have taken an object and pull the screwdriver down then the lid up*
- *He will add the force of centrifugal, and more power*

The above excerpts seem to confirm what has been already mentioned earlier that the subjects have problems in applying scientific concepts and principles used in the groups obtained very low mean percentages (i.e., 7-20%). About a third of the subjects in C_2, a fifth in C_1 and a tenth in E were able to state the principle and got full marks. More than four fifths of the subjects in E and C_1, and about three-fifths in C_2 could not and got a zero score. Those who could not either mistook it for the principle of conservation of energy or simply stated the moment of a given single force. For example:

- *Force is directly proportional to distance*
- *Force x perpendicular distance and the limit of stretch*
- *Is that the downward force equals the upward force*
- *The principle of moment applied is that: the greater the distance from the fulcrum, the greater the turning effect*
- *If force applied near the fulcrum it is difficult to push or pull an object but when force is applied away from the fulcrum then it easier*
- *Force is directly proportional to the mass and distance*
- *The screwdriver is directly proportional to the tin*

The above statements vividly demonstrate what was mentioned earlier that the subjects had conceptual problems concerning the concept the principle of moments. As indicated earlier, some of the subjects seem not to have grasped this concept. Apart from the recurrent issue of linguistic, conceptual and procedural problems, the list of statements made by the subjects in this and other questions reflects poor instructional outcomes. In other words, there seems to be a cognitive gap between what is supposed to have been taught and what has actually been learned.

Q 3.6 was a follow up of Q3.5. The subjects had to use their answer to Q3.5 (principle of moments) to answer the question. The results show that the subjects in C_1 got a higher mean (0.82) than those in the other two groups. The mean for C_2 was 0.68, and for E, 0.25. The mean percentages for all were less than 50%. About a third of the subjects in C_2, a quarter in C_1, and only one-twentieth in E got full marks.

- *Sipho's hand has no force*
- *It was because there was no air inside the tin*

From the foregoing, it seems evident that the subjects, as earlier mentioned, are rarely able to apply learned concepts to everyday life situations (Solomon, 1985). They seem not to have grasped the concept of the moment of a force. This has resulted in their inability to recognize and use it in explaining the process of opening a paint tin.

The subjects were required to draw a pivot point for question 3.2, and an arrow showing the direction of a force for question 3.3 on a diagram showing a screwdriver Sipho used to open the lid of the tin of paint. The results reveal that the mean percentages for question 3.2 were above 50% for all the groups while the mean percentages for question 3.3 were all below 50%. About three quarters of the subjects in C_2 and E, and about two fifths in C_1 were able to mark the pivot point. About two fifths of the subjects in C_1, a fifth in E and C_2 could not. 42% of the subjects in C_2, 27% in C_1, and 19% in E drew the arrow showing the force at the right place. Also, 73% of the subjects in C_1, 58% in E, and 55% in C_2 wrongly placed it.

In Q3.4 the subjects were supposed to calculate the moment of a 20N force about a pivot. The results show that there were more subjects in C_2 (48%) who got the total mark than subjects in E (21%) and C_1 (20%). The mean percentage for C_1 was less than 50% while that of E and C_2 was above 50%. About a quarter of the subjects in C_1, and about a fifth in E and C_2 could not calculate the moment of the force and got a zero score.

Q3.5 asked the subjects to state the principle of moments. The results show that all were used to test the subjects' traditional and scientific worldviews predispositions. The implication of this for the teaching-learning process will be elaborated further in a later section.

Question 3, divided into seven sub-sections, is about a boy, Sipho, who was trying to open a tin of paint. For this question, the subjects were expected to use at least one or two of the assessment framework categories such as: conceptions of scientific concepts, process skills and application of scientific knowledge. Q3.1 required the subjects to explain, in terms of the principle of moments, why Sipho could not open the lid of a tin of paint using his bare hands. The results show that the mean percentages for E and C_1 were less than 50%. About three fifths of the subjects in C_2, two fifths in E, and a third in C_1, gave the correct reason why Sipho could not open the tin lid with his bare hands such as:

- *The force was applied at a short distance*
- *His hands are shorter than the screwdriver. Long levers does a good work than shorter ones*
- *The distance with his hands is very short and it would be very difficult to use bare hands*

The rest of the subjects gave wrong reasons. Their responses revealed both commonsense knowledge and alternative conceptions such as:

- *It was because Sipho's hands could not fit in the lid and they were short so the surface area for moment was less*
- *Because his hand was not strong enough to open like the screwdriver and the screwdriver was long for opening easily*
- *It is because there was no distance to be moved*
- *His hands are not strong enough, they can bend while the screwdriver cannot Because the hands has no power to open the tin*
- *No force was applied*
- *Force is a pull so Sipho can't pull or open using his hands it will damage his hands*

a moment of a force to identify examples of its cases around their home environment. The overall mean percentages on this item were 92% for the subjects in E, 90% for C_2, and 49% for C_1. About nine tenths of the subjects in E and C_2 answered the question correctly while almost half in C_1 did so. About half of the subjects in C_1 and almost a tenth in E and C_2 failed to give the correct response to the question and got a zero. Some of their responses are as follows:

- *If you are on your way to the dip tank where cows goats and sheep dip*
- *Mum carrying a bucket of water. A boy lifting bundles of firewoods*

These comments seem to verify Solomon's (1985) argument that students find it difficult to transfer the physics concepts they have learned successfully in a physics context to a context of everyday objects. They could not apply the concept of moment of a force even though they had successfully defined it in their own words in Q1.1.

Question 2, which has three subsections, is concerned with a girl, Siphiwe, who used a wheelbarrow to fetch water from the river. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception and application of valid scientific rather than alternative conceptions. In Q2.1 the subjects were given a drawing of the wheelbarrow with three points marked on its handles. They were supposed to use their knowledge of moments of a force to identify the best position at which Sophie could handle the wheelbarrow. The subjects in E obtained the highest mean (0.88) or the highest percentage (88%) in that they chose P as the easiest point for handling a wheelbarrow. The subjects in C_1 came next with a mean of 0.84, or 84% getting full marks in the same question. The subjects in C_2 came last with a mean score of 0.77 or 77%. Further, 16% of the subjects in C_1 and C_2 got zero percent while 13% in E did so. Questions 2.2 and 2.3

number of subjects from all three groups that obtained a zero. It is worth noting that there were more subjects in C_1 who got zero in the post-test than those who did so in the pre-test in the questions marked with a star (*). A further breakdown of the results is made for each question in the rest of the section.

Question 1 deals with the concept of moments of a force and is divided into two sub-questions. This question expects that the subjects would use at least one or two of the assessment framework categories such as: conception and application of scientific knowledge. In Q1.1 the subjects were supposed to define what was meant by moment of a force using their own words. The moment of a force is force applied at a perpendicular distance or the turning effect of a force (Boyle and Williams, 1991). An inspection of Appendix 8 shows that the overall mean percentages for all the three groups in this question were above 50%, and more than half of the subjects were able to define the moment of a force and got full marks. However, two fifths of the subjects in E, a third in C_1, and a quarter in C_2 could not define the concept and got zero for the question. The following are some of the alternative conceptions evident in their responses:

- *Moment of a force is that cannot be made or destroyed or is the amount of force applied on an object*
- *It's when energy is applied on an object and an object move.*
- *Moment of a force is that is applied for something to do work.*
- *Moment of a force if force found around your area.*
- *Moment of a force means things that need force in order to be done.*

The above excerpts reveal that the subjects had conceptual and linguistic problems. They seem not to have grasped the concept of moment of a force. Some are confusing the concept with energy while others are confusing it with the amount of work done. In Q1.2 the subjects were supposed, as in Q1.1, to use their knowledge of percentage of 54%, a mean score of 0.54 with a standard deviation of 0.48 for Q1.1, which required the subjects to define the moment of a force. Also 50% of the subjects from group E got full marks and 42% got zero for the question. The subjects from groups C_1 and C_2 got mean percentages of 69% each in Q1.1. About a third of the subjects from both groups got zero and about two thirds of them got full marks.

A further examination of Appendix 8 shows that, to a large extent, the same questions turn out to be difficult for most of the subjects in all the three groups. For instance, all the groups obtained a mean percentage of less than 50% in the questions dealing with:

- The application of principle of moments when opening a paint tin (Q3.3, 3.5, 3.6)
- The calculation of the acceleration of, and the force exerted on a moving car (Q4.2, 4.3, 4.4)
- Designing an investigation for Hooke's law (Q5.1);
- The identification of the friction as well as the calculation of the acceleration of a block (Q6.1, 6.2)
- Identifying the type of energy involved in the scenario (Q7.3)
- Explicating a case of efficiency (Q8)
- Calculating the energy and speed of a hoe (Q9.3 and 9.4)

All the groups performed well and got mean percentages that were more than 50% in questions 2.1, 3.2, 7.1 and 7.2. Question 2.1 had the highest average mean percentage for all three groups while Q9.5 had the lowest. Q7.4 had the highest number of subjects from all the groups that obtained full marks while Q9.5 had the lowest. No single subject got full marks in Q9.5 in all the groups. Q9.5 also had the highest that is, the science subjects were their first choice. What is more, they had smaller numbers than group E. Another possibility could be the number of repeaters in each group. The experimental group had the highest number of repeaters, implying that they were at a lower cognitive level than the other groups. However, time constraints and distance could not allow the researcher to look into all these factors.

4.4.2 THE SUBJECTS' CONCEPTIONS OF FORCE, ENERGY, WORK AND POWER

In this section the subjects' conceptions of force, energy, work and power are examined in terms of their performance on the post-test PAT instrument. The study will investigate: (1) the problems being encountered by the subjects regarding the concepts of force, energy, work and power; (2) the patterns of performance that emerged; (3) the process skills and conceptions of force, work, energy and power that were mastered and those that were not; (4) the ability of the subjects to recognize or use science in their daily lives; (5) the ability of the subjects to apply scientific principles to solve practical problems; (6) the performance of the subjects when confronted with contextualized tasks; and (7) the evidence of alternative worldviews in the subjects' conceptions of force, energy, work and power.

Appendix 8 shows the mean percentage, the mean, the standard deviation, the percentage of students who scored zero, and the percentage of those who scored the full marks on each item per group. The mean percentage is calculated from the total raw scores per item divided by the total number of students times the total marks on the item, and multiplied by 100 while the mean scores and the standard deviations are based on the raw score only. For example, the subjects from group E got a mean find out where, the Scheffe' test (Gay, 1981) was applied producing F-values of 0.79 between groups E and C_1, 6.52 between groups E and C_2, and 10.67 between groups C_1 and C_2. Since the value of F required for significance is 2.125, it can be concluded that there was no significant difference between the means of groups E and C_1 while there was a significant difference between the means of C_2 and the other groups. Further, a comparison of the grand means difference was undertaken to determine which group outperformed the other (see Table 4).

The grand mean differences of groups E and C_1 were negative indicating that the means of both groups were smaller than the grand mean while that of C_2 was positive. Thus it can be concluded that group C_2 is in a better position than groups E and C_1 on the PAT. This inference seems to imply that the exemplary instructional strategies were only effective in the second control group and not in the experimental group. This raises further questions. Could other extraneous factors (e.g. class size, researcher bias, resources, time tabling, etc) that were not in the other groups have influenced the performance of the second control group? Is it possible that the second control group was at an advantage in terms of syllabus coverage? This could not be established since they had not written a pre-test. Is it likely that subject combinations could have affected the experimental group? The researcher discovered that although the three groups were comparable in terms of school performances in the Cambridge Ordinary level results, they were following different programs. For instance the subjects from the experimental group took science as a compulsory subject and had to make choices between History, Home Economics, Technical Drawing, Wood Work, Accounts and Additional Mathematics. The subjects in Group C_2 and C_1, on the other hand, had deliberately opted for Science and other related subjects (e.g. Mathematics), and C_2, exposed to exemplary instructional material on the PAT, were higher than that of C_1not so exposed. However, C_2 had the highest mean of 26.11 with a standard deviation of 7.41 followed by E with a mean of 19.90 and a standard deviation of 6.61and lastly C_1 with a mean of 18.01 and a standard deviation of 6.71. The high standard deviations suggest that the groups were heterogeneous.

These descriptive statistics above give rise to the following questions: (1) Are the higher means of the treatment groups statistically different? (2) Is the observed difference attributable to the effect of the exemplary instructional material? A One – Way Analysis of Variance (ANOVA) was carried out to determine the nature of the differences in the post-test means.

The ANOVA results of the post-test scores for all the three groups are shown in Table 5 below. As can be observed, the F ratio (13.17) for the post-test scores is greater than the critical F-value of 3.07 (i.e., F, (2, 125) = 3.07 at $p < 0.05$) needed to falsify the null hypothesis, which expects no differences in mean scores. This suggests significant

Table 5: Analysis of Variance of the Post-test Scores on the PAT

Source	df	SS	MS	F
Between J-1	2	1500.14	750.07	13.17
Within N-J	125	7117.85	56.94	
Total N-1	127			

Significant p<0.05

differences among the groups involved in the study. The only thing the F-value revealed was that there was at least one significant difference somewhere. In order to

- Scientific versus alternative conceptions or traditional worldviews.

4.4.1 OVERALL PERFORMANCE ON PAT

After groups E and C_1 had written the pre-test (see results in Table 2 in section 4.2), the experimental group (E) and the second control group (C_2) were exposed to a treatment using exemplary instructional approach involving the use of concept mapping and enriched with indigenous knowledge commonly encountered in their socio-cultural environment. Concept mapping was used to help the subjects to learn meaningfully so that they could make meaningful links between the science concepts taught in class and some everyday life phenomena found in their socio-cultural environment (Adamcyzk et al., 1994; Kinchin, 2001; Brandt et al., 2001). The socio-cultural approach was an integration of the subjects' socio-cultural experiences into the lesson plan. For example the subjects were encouraged to discuss openly in small groups their socio-cultural beliefs versus scientific concepts at the beginning of the various topics taught during the intervention (see chapter 3 for the details).

The three groups wrote the PAT as post-test and obtained mean scores shown in Table 4 below. An examination of Table 4 shows that the mean scores of the two groups, E

Table 4: A Comparison of the Post-tests Mean Scores and Standard Deviations on the PAT

Group	N	Mean	Grand mean difference	S.D
E	51	19.90	19.90 – 21.31 = -1.41	6.61
C_1	46	18.01	18.01 – 21.31 = -3.3	6.71
C_2	31	26.11	26.11 – 21.31 = 4.7	7.41
Entire group	128	21.31		6.91

into the science classroom from the traditional society and the scientific explanation of natural occurrences (Jegede and Okebukola, 1991b)

Some science educators, such as Dienye and Gbamanja (as cited in Emereole, 1998), have objected to the fact that in the literature, the African has been labelled superstitious and unscientific in his thinking. Dienye and Gbamanja argue that

> If rational thinking is the basis for such a label, then a serious mistake has been made because Wiredu (1980) has opined that rational thinking is the *sine qua non* in the survival of any society. One may think that preoccupation with the belief systems in Africa may have given rise to the erroneous opinion that the African was unscientific. Of course the overlap between the rational and the metaphysical worldviews is not peculiar to African cultures. Not only that superstitious beliefs exist all over the world, but in fact that many so-called superstitions in different cultures very often do have scientific, rational and moral bases (Emereole, 1998: 68)

It seems that the debates about traditional beliefs and science will continue for some time to come. This is inevitable because in one sense one is probably comparing thought systems based on very distinct assumptions. In another sense researchers are insufficiently equipped to critically analyse oral traditional and concomitant beliefs and practices associated with such a worldview. We must concede the fact that as far as verbal art is concerned we are greatly disadvantaged.

5.3 THE EFFECT OF AN INTERVENTION ON STUDENTS' CONCEPTIONS OF FORCE, ENERGY, WORK AND POWER.

Another aim of the study was to investigate whether or not there would be any significant difference between the scientific and/or traditional views held among Swazi secondary school students who were exposed to different teaching and learning strategies. This was to find out if an exemplary instructional approach involving the use of concept mapping that integrates indigenous knowledge with school science would have an effect on the learners' conceptions of force, energy, work and power.

As already mentioned in Chapter 3, concept mapping was chosen for this particular study because it has been found to enhance the subjects' ability to apply what they learn at school with what they learn outside the school environment (Ebenezer and Connor, 1998; Novak and Godwin, 1984; Ault, 1985; Austin and Shore, 1995). Regarding concept mapping, Heinze-Fry and Novak (1990) have asserted that the use of concept mapping as a teaching strategy facilitates meaningful learning in that it enhances integration and retention of knowledge by increasing the number of relevant concepts that can be connected to new material. According to Eggen and Kauchak (1994), concept mapping helps learners to not only understand how the concepts they learn are related to others, but to also relate them with information already in the long-term memory. They point out the importance of presenting science concepts in richly complex and contextualized frameworks in order to enhance the retrieval of information from the long-term memory. Eggen and Kauchak (1994) have argued further that the retrieval of information depends on: (1) how well the information has been encoded in the long-term memory; and (2) how the new scientific information has been embedded into everyday problems, which the learners can relate to and which in turn enriches the encoding process. In other words, concept mapping was used to help the subjects to learn meaningfully so that they could make meaningful links between the science concepts taught in class and some everyday life phenomena found in their socio-cultural environment.

The effectiveness of the concept map as a learning tool was demonstrated during the lessons when the subjects were able to give examples of how the concepts they were learning could be applied in things around them. For example, they were able to recognize and describe the energy conversions in the activity of raising a bucket of water from the ground and placing it on one's head, a practice common in their socio-cultural environment. Although it was observed as in earlier studies (e.g. Rollnick and Rutherford, 1996; Rollnick, 1998; Ogunniyi, 1999), the subjects were faced with a language challenge (as second language learners) in that they could not readily come up with connecting words or links between the concepts (see section 3.6.1), at the end of the intervention it was realized that the subjects' concept map construction skills had greatly improved (see Appendix 6) than at the beginning (Appendix 5).

As mentioned earlier, the prime aim of an exemplary culturally sensitive instructional strategy was to provide a teaching/learning situation that would be easily accessed by learners in traditional settings (George, 1999b). It was hoped that the exemplary instructional strategy would help the learners to bridge the gap between their worldviews and the scientific valid view of force, energy, work and power. Each lesson was made culturally relevant by employing Manzini's (2000) method based on Jegede's (1995) eco-cultural paradigm proposed to enable learners from non-Western cultures to cross the borders between their traditional worldviews derived from their socio-cultural environments into school science (see details in Chapter 3). The analysis done on the subjects' responses during the videotaped group discussion seemed to suggest that some of them were able to either *manage* the border crossing or experience a *hazardous* transition (Aikenhead, 1996) on some of the concepts such as moments of a force, principle of moments, energy, work, and efficiency. There were also some instances of impossible border crossing where the students stuck to their traditional worldview presuppositions when explaining some natural phenomena.

The ANOVA results of the post-test scores for all the three groups in section 4.4.1 showed that the F ratio (13.17) is greater than the critical F-value of 3.07 suggesting significant differences among the groups. However, Scheffe's test revealed that there was no significant difference between the means of groups E and C_1. What is more, a comparison of the grand means difference that was undertaken to determine which group outperformed the other revealed that the grand mean differences of groups E and C_1 were negative indicating that the means of both groups were smaller than the grand mean while that of C_2 was positive. It was concluded that group C_2 was in a better position than groups E and C_1 in the PAT. This inference implied that the exemplary teaching-learning strategies based on concept mapping and cultural integration was only effective in the second control group and not in the experimental group. This suggests that there were other extenuating factors such as subject combination (academic programme), school culture, or the subjects' reaction to the researcher rather than to the instructional strategy (Leach and Scott, 2000).

Although on the whole, the male subjects outperformed their female counterparts, the difference in the PAT is not statistically significant in the second control group. It seems pertinent to begin to re-analyse the sort of achievement tests that have painted a negative picture of the female learners' abilities for science. As Ogunniyi (1999) has suggested, it might be necessary to examine more closely the features of these tests and the contexts they reflect before reaching any conclusion. On the other hand, it is interesting to note that age did not affect the subjects' performance on PAT in all the groups while that the subjects' interest in science did so to a certain degree. It is hoped that future studies would attempt to explore the effects of concept mapping and cultural integration approaches on a broad range of topics over a longer period of time and using a larger sample size than was available for this study.

An assessment framework adopted from the STL project (Ogunniyi, 1999) was used to test the subjects' performance in terms of process skills, conception of scientific concepts and the application of scientific knowledge and skills when answering the PAT. The process skills included the use of graphical and symbolic representation such as the construction and interpretation of graphs as well as competence in calculating; the accurate reading and/or estimation of common measurements; and the planning scientific investigations. The conceptions of scientific concepts and principles were in relation to the topic of Force, Energy, Work and Power. The innovative application of scientific knowledge and skills refers to how the topic under study could be used in the context of the subjects' socio-cultural environment.

As already reported in the last chapter, an examination of the responses to the PAT revealed that a relatively high percentage of the subjects had linguistic and conceptual problems. For instance:

- The subjects had problems with questions that demanded process skills such as calculations (Q3.6; Q4.1; Q4.2; Q4.3; Q4.4; Q6.2; Q9.4; Q9.5). The means for these questions ranged between 0% and 52% for the experimental group (E) and the two control groups (C_1 and C_2)
- They had problems with respect to such process skills as drawing, reading and interpreting graphs (Q4.4; Q5.2), the mean percentages ranged between 24%

and 43% while for planning investigations (Q5.1) the mean percentages ranged between. 13% and 51%.

- The subjects' conception and application of scientific concepts and principles was also weak. A relatively high percentage could not
  - Identify, explain the principle of moments (Q3.5); the mean percentages ranged between 7% and 20%
  - Apply the everyday life concept of friction (Q6.1; Q11); the mean percentages ranged between 31% and 55%;
  - Apply the concept of energy conversions to a contextualized situation (Q7.3; Q9.1 to Q9.3); the mean percentages ranged between 35% and 55%.

The findings depicted in the above paragraph are similar to the findings of Golding and Osborne's (1994) study in which at least 50% of the learners had considerable difficulties with the basic concept of energy and its related ideas, and their application to everyday life.

Problems associated with second language learners (Rollnick, 2000; Duran, Dugan and Waffer, 1998; Rollnick and Rutherford, 1996) also emerged from the subjects' responses. The subjects seemed to have linguistic handicaps that prevented them from writing or expressing their understanding about force, energy, work and power in a concise manner. If anything at all, the findings of this study have shown the critical importance of language in understanding school science or any subject for that matter. Apart from copious grammatical problems relating to spelling errors and incoherent sentence structure, the role of tenses, and the issue of substitution (i.e. the error of substituting a form from siSwati to English) was also observed. As already mentioned in chapter 3 and in the above discussion, the subjects' greatest challenge as second language learners in constructing concept maps, was writing the connecting words or links between the concepts. They could not readily come up with the right propositions even though they demonstrated an understanding in their mother tongue of how the concepts were linked to each other. Rollnick (2000) has argued that second language learners are faced with a double challenge of learning two languages at once: that of school science and English, which is not their mother tongue. Kulkarni (1988) has observed that the language factor has at least two aspects, which affect second language learners namely: (1) the difference between everyday language use of the terms and the scientific use of the same term (e.g. the words "force, work, energy and power"); (2) the combined effect of insufficient English, on the one hand, and the cultural background, on the other. Good and Shymasky (2001) have cited the British biologist Lewis Wolpert as asserting that science is counter -intuitive, even unnatural. The instructional challenge here is how to help students reconcile their natural and personal pre-scientific language with the highly sophisticated and impersonal language of science. The attempts that have been made in this regard will be discussed later under the so-called "African Learner Model".

The assessment framework adopted from the STL project also included a category that investigated whether or not the subjects held scientific, alternative or traditional worldviews about certain natural phenomena. The responses to questions 2.3, 2.4, 9.6 and 9.7 of the PAT revealed that the subjects of this study hold a multiplicity of worldview presuppositions. Their comments were embedded within their traditional worldview presuppositions, commonsense knowledge, and to some extent the scientific knowledge notions of the phenomena in question. These comments create an apposite point of departure to consider how the subjects have attempted to reconcile their natural, commonsensical notions about diverse phenomena with the counter-intuitive notions.

Currently in the field of science education there appears to be a raging war of words played out in the names of multiculturalism and constructivism. Both the proponents and critics of both movements are debating the nature of science without reaching any consensus. Those in favour of multicultural science want indigenous knowledge to be integrated into school science while the critics argue for exclusion. To the former, science is a cultural enterprise while to the latter accurate scientific explanations devoid of universal application is not science (Good and Shymansky, 2001).

5.4 SUBJECTS' TRADITIONAL AND SCIENTIFIC WORLDVIEWS OF SELECTED NATURAL PHENOMENA

The study was premised on the constructivist belief that for learners to understand school science, they need to exercise a sort of cognitive 'border crossing' between their natural, commonsensical and intuitive worldviews and the rather unnatural and counter-intuitive scientific worldview. In an attempt to understand the phenomenon of border crossing the study searched the literature for relevant theoretical constructs in the area and found the Border Crossing Theory (Aikenhead, 1996), Collateral Learning Theory (Jegede, 1995) and the Contiguity Learning Hypothesis (Ogunniyi, 1995) most appropriate for analysing the subjects' alternative conceptions of the selected phenomena. Details of each theoretical construct had earlier been presented in Chapter 2. The subjects' alternative worldview presuppositions were vividly demonstrated in their responses to two fictitious stories based on some traditional practices in Swaziland. An analysis of the subjects' responses to the fictitious stories has actually confirmed the appropriateness of the three selected theoretical constructs for analysing the subjects' responses.

Both the quantitative and qualitative data have indicated that the subjects do exercise border crossing both collaterally and contiguously. Aikenhead's (1996) types of border crossings were demonstrated in conjunction with Jegede's (1995) types of collateral learning, such as: managed border crossing and parallel, secured collateral learning; hazardous border crossing and either dependent with no collateral learning, i.e., the rejection of the scientific worldview; impossible border crossing and possibly dependent, if at all. For example, in the case of managed border crossing and parallel collateral learning: the results of the post-test on question 2 in the Physics Achievement Test seemed to suggest that although a considerable number of the subjects had *managed* to cross the border between their traditional worldviews and that of school science (in that they were able to correctly answer Q2.1, a question based on a scientific worldview), they however, continued to adhere to their traditional worldviews before and after the tests with regards to Q2.2 and 2.3 (questions based on traditional worldviews), hence demonstrating a case of *parallel collateral learning*. However, other than identify the different types of border crossing, the two constructs (the Border Crossing and Collateral Learning Theories) do not seem to provide how border crossing takes place. In other words, they only provided ways of identifying and/or describing incidents of border crossing not how such a process occurs. In another sense they seem rigid by grouping the subjects into fixed categories and leaving no room for shifting from one type of border crossing/

collateral learning to the other, which might come as result of a variety of factors exerting their influences on the subjects' attitude towards school science.

The contiguity hypothesis, however, attempted to delve into the mechanism of border crossing. It depicts border crossing as a dynamic rather than a fixed process. As mentioned earlier in Chapter 2, the construct proposes that border crossing depends to a great extent on the context and interest being served. Hence the type of border crossings that occurs, whether it be collateral or multilateral will depend on a host of factors such as the: (1) the consequences of a given response; (2) the interest or satisfaction derived from a learning experience and (3) the desire to gain mastery over a learning task or the challenge of meeting peer, teacher, parent or societal expectations and so on. The construct uses physiological, psychological and philosophical explanations to explicate the process of border crossing from traditional beliefs and commonsense experience to that of school science. An allusion to the construct was that it assumes that the cognitive apparatus of the learner as well as his/her entire body are involved in the process of learning (in section 2.7.1). It assumes that a learner's cognitive structure consists largely of three basic worldview schemata: traditional beliefs, commonsense – intuitive knowledge and science – all derived from his/her culture, school and life worlds as a whole (see Fig. 1). Each schema consists of elements of the other two schemata to a greater or lesser degree. Hence, a scientific schema is largely constituted by elements of science based on human experiences with nature relating to reality of space based on facts; the reality of time in terms of its continuous, irreversible series of duration; the reality of matter as existing within time and space; the orderliness of the universe; the universe as the product of chance and evolution; the causality of events and the human ability to understand the universe (Ogunniyi, 1986). But in addition to the scientific elements, the scientific worldview schema also has elements of common sense and rationality as well as interest and value system or ethical dimensions beyond strict scientific empiricism (Ogunniyi, 1986, 1987, 2000). For instance, a scientist is expected to be rational, honest, open-minded, objective, sceptical, persevering; show great interest and enthusiasm for his/her work, etc. But these elements are not restricted to the scientific worldview. They are in other worldviews as well. Hence in this regard, the scientific worldview schema is unique only to the extent it is galvanized largely by its fundamental assumptions about nature.

The traditional cultural beliefs schema also consists of elements of science and common sense and related assumptions but it is largely couched in, and propelled by its religious and metaphysical assumptions such as: space is real but incommensurable; time is real, continuous and cyclical; matter is real and exists within time, space and the ethereal realm; the universe is orderly, metaphysical, mystical and unpredictable; events have both natural and unnatural causes; humans have the capacity to interpret certain aspects of nature and can use magical and metaphysical means to control natural forces; the universe was created and neither the product of chance nor evolution, etc (Ogunniyi, 2002a). The commonsense schema largely driven by intuition, cultural education and experiences also has elements of rationality, science and cultural beliefs. Hence, while commonsense shows that the sun rises in the east and sets in the west, science would say the sun remains fixed in the centre of the Solar System and it the earth that is rotating and revolving around the sun. Commonsense sees a flat earth; science sees a spherical earth and so on. For this same reason, commonsense language based on everyday experience is inadequate in a scientific discourse and vice versa (Ogunniyi, 2002b).

Ogunniyi (2002b) states further that all the three major schemata are in a state of dynamic flux and are triggered off by contextual circumstances in which an individual finds him/herself or the interest to be served. Hence, an individual in one context may maintain a scientific mentality by basing his/her behaviour largely on scientific assumptions while at another setting his/her behaviour is galvanized largely by a religious demand, and yet at another time, it is just plain use of commonsense. This should not be surprising if we consider the range of experiences to which an individual may be exposed within a day. Some circumstances would demand the application of scientific reasoning while others would demand a religious worldview. What seems important is how to adapt to the flux of change in one's environment. This was demonstrated by three subjects of the study: Langa, Mandla and Khangezile in sections 4.6.3.1 to 4.6.3.3. Their worldview presuppositions seemed to be influenced by either the context (dominated by either a scientific or traditional worldview) or by the human interest being served.

Rollnick (2000) has observed that the Border Crossing and the Collateral Learning theories have not considered the issue of language in their exposition, which notion also applies to the Contiguity Hypothesis. The central role of language as an intellectual tool in the learning process cannot be underestimated. According to Rollnick (1998):

> Language is a central factor to all learning. Its importance in the learning of science has often been underestimated, as there is a belief that the student's meaning will 'come through' despite language difficulties. The issue of language

> cannot be ignored as it impinges on the learning of science in important ways related both to attitude and cognition (p.21)

Chomsky (2000) construes language as originating from a genetically programmed mechanism, which he dubbed "Language Acquisition Device" (LAD). Piaget (1926), on the other hand, sees language as evolving from a combined effect of sensations and actions, which in turn nourish thoughts. Despite the various notions on the source of language, there is consensus among scholars that language plays a mediation role in thought.

Rollnick (2000) asserts, "the view of learning as situated cognition considers language to be integral to social practices or to the culture in which the learner engages as a legitimate peripheral participant" (p 99). According to Ellerton (1999) theories based on Vygotsky and situated cognition have resulted in a holistic view of culture that encompasses language. Vygotsky (1986) regards language as an intellectual tool for thought and a means for interacting with our environment. To Vygotsky, speech, which commences as a labelling mechanism, soon assumes an instrumental function for the learner in terms of furnishing him/her with the essential logical connections to express his/her thought or to understand the thoughts of others. Mousley and Clements (1990) define culture as an over riding concept embracing language:

> The term culture generally refers to a social heritage- those characteristic behaviours, which are transmitted from one generation to the next. While the notion of culture includes collective mental artefacts such as symbols, ideas, beliefs and aesthetic perceptions.... it also embodies the distinctive forms of discourse... (p. 398)

There is, therefore, still a need for further research in the area. It is with this view in mind that this study has proposed the so-called African Learner Model as a possible extension of the Contiguity Learning Hypothesis. It combines the three theoretical models to show how, when, and under what conditions the various types of border crossings and collateral learning might occur within the mind of a learner living in an African socio-cultural context. The model also elaborates the issue of language and situated cognition.

5.5 THE AFRICAN LEARNER MODEL

As has been mentioned earlier, some African science educators (e.g. Jegede, 1995 and Ogunniyi, 1997) have noted that a learner within the African socio-cultural setting is a person of two worlds: that of African culture and that other world where science has, to a certain extent, become a dominant cultural factor. They have observed that a learner in an African social context (henceforth, the African learner) often finds him/herself operating in two distinctly different worlds. Jegede (1995) has argued that learning is a holistic process for the African learner that is governed by a knowledge base, which ranges from factual knowledge to beliefs and customs. The African learner's worldview serves as an antecedent to cognition within his/her culture that involves such things as communal organization, theory of knowledge, concept of causality, authoritarianism, goal structure, kingship system, storytelling and riddling. This will cause the African Learner to come to school with a load of mysteries that plague him/her mind (Jegede, 1995). He has further argued that if care is not taken, these mysteries, usually tagged as "superstitious", could cause a blockage to any science knowledge the learner might acquire as a result of schooling. Hence, the African learner finds him/herself having to cross the cultural border between his/her African worldview and that of school science as he/she learns scientific concepts presented to him/her in the science classroom.

The ***African Learner Model*** proposed below is an attempt to depict the cognitive explanation of **how** an African learner crosses the cultural border between his/her African worldview, derived from his/her socio-cultural environment, and the science worldview he/she encounters in his/her science classroom. The model is derived from Aikenhead's Border Crossing Theory (Aikenhead, 1996), Jegede's Collateral Learning Theory (Jegede, 1995), Ogunniyi's Contiguity Learning Hypothesis (Ogunniyi, 1995) and studies dealing with language and situated cognition (Aikenhead and Jegede, 1999; Wortham, 2001; Rollnick, 2000; Ogunniyi, 1996, 1997, 2002a and b; Aikenhead and Jegede, 1999; Duran, Dugan and Waffer, 1998; Jegede, 1995; Jegede and Aikenhead, 1999; Eggen and Kauchak, 1994; Ashman and Conway, 1993; Novak, 1988; Woolfolk and McCune Nicolich, 1980; Moates and Schumacher, 1980; Johnstone, 1997).

5.5.1 The Environment And Ecosocial Systems

The shaded region in the African Learner Model (Fig. 7) illustrates the fact that the mind of the African learner functions within the traditional socio-cultural environment. He/she succeeds at cognitive tasks by virtue of mediating structures or processes, which are embedded in the socio- cultural environment. His/her cognitive accomplishments result from "intact activity systems" that can include mental, social, physical and symbolic structures that are interrelated to allow successful action (Wortham, 2001). The mental refers to his/her mind; the social to his/her interactions with the significant others e.g. teacher, peers, members of cultural environment; the symbolic to language systems e.g. talking, writing, diagrams, formulas and other symbolic means of constituting meaning (Duran, Dugan and Weffer, 1998); and the

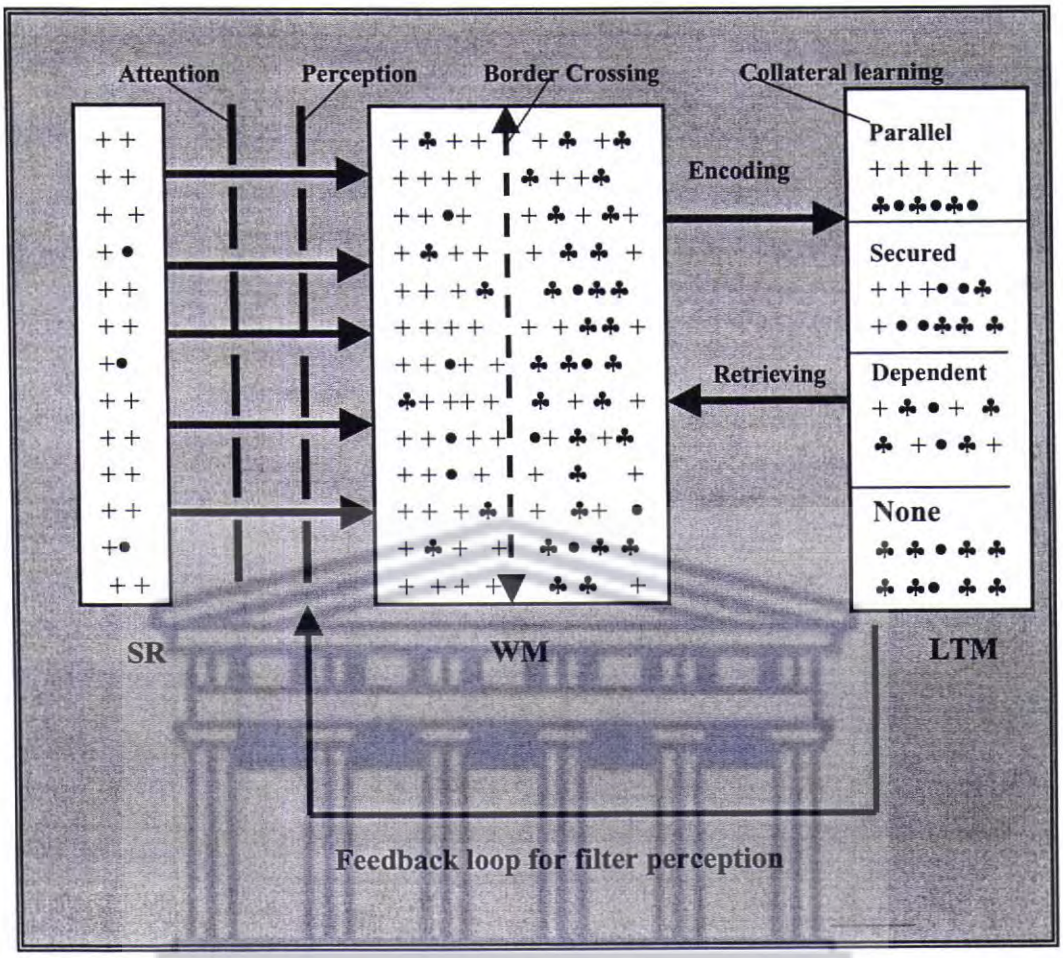


Fig. 7: THE AFRICAN LEARNER MODEL

Key:
- **SR:** Sensory Register
- **WM:** Working Memory
- **LTM:** Long Term Memory
- +: Scientific Worldview
- ♣: Traditional Worldview
- •: Commonsense

physical to his/her embodied experiences (Ogunniyi, 2002b). Wortham (2001) refers to these systems as "ecosocial systems". He argues that:

> Cognitive accomplishments depend on systems that connect various structures and processes, including but not necessarily limited to aspects of the individual person, the tool mediated activity and the socio-historical situation. (Wortham, 2001: 38).

5.5.2 The Receptors And Sensory Register

As the African Learner (AL) sits in a science classroom, stimuli from the science classroom environment constantly bombard his/her receptors (R: eyes, nose, skin, ears, etc). The stimuli enter the AL's sensory register (SR) where they are held in icons (visual) and echo (sound), feeling of touch, smell, etc. The latter are holding mechanisms that allow additional processing to continue for a brief period after the environmental stimulation (e.g. teacher talk, classroom discussion, hands-on experiences, etc) has changed or terminated. According to Moates and Schumacher (1980), the African Learner (AL) does not wait passively for information about a scientific phenomenon; rather he/she actively seeks information that is relevant to his/her purpose. They suggest that a psychological concept that captures such activity is the concept of schema. Schemata are mental structures, which are units for representing the AL's internalized and organized knowledge of the world. All of the AL's knowledge of his/her world is held in various schemata. They function as information accepting systems for picking up the information from the environment. They prepare the AL for particular types of stimulation, and if that stimulation occurs, the AL's schemata become activated. The AL's schemata in this case are activated (as the *Contiguity Hypothesis* suggests) by the context of the scientific phenomena being presented such as class discussion or instruction.

5.5.3 Attention

Information processing begins when the African learner pays attention to the stimuli (scientific phenomena) presented in his science class. According to Moates and Schumacher (1980), at this moment the African learner's mental activity is generally distributed to the tasks (e.g. looking and listening) he/she is performing at the given time. According to Woolfolk and McCune Nicolich (1984), he/she does this by:

- Reorganizing the scientific phenomena such that it becomes simpler, more complete, more regular, and more related to his/her African worldview.
- Using feature analysis, that is, searching for basic elements or features similar to his/her African worldview in order to recognize the scientific phenomenon.
- Using the context of the situation, that is, what he/she already knows about the words or pictures presented, or the way the world already operates which is derived from his/her worldview presuppositions acquired since childhood.

The view above agrees with the basic tenet of the *Contiguity Hypothesis*. According to Ogunniyi (2002b), as espoused in his Contiguity Hypothesis, the mental faculties of the AL become activated "depending on the influence of the dominant worldview presuppositions or assumptions at work and the human interest being served." (p. 8)

The teacher plays a major role in the process of attention. He/she must consciously plan from the commencement of the lesson how to draw the AL into the lesson and maintain his/her attention. The interaction between the AL, teacher, and peers forms the social part of the eco-social systems. The teacher might deploy the use of symbolic and instructional tools such as lectures, demonstrations, discrepant events, visual displays, emphasis and discussions (Eggen and Kauchak, 1994) to create an enabling environment as well as consolidate his/her attention and focus on the learning tasks.

5.5.4 Perception

Once the AL's attention has been captured, he/she then starts to perceive the scientific concepts being presented by attaching meaning to the information received from his receptors. The meaning he/she attaches to the scientific phenomena is not only dependent on his or her past experience but also on what he or she expects to happen. Moates and Schumacher (1980) argue that the sampling of information from the socio-cultural environment (shaded region) is guided by the AL's internal expectation, which direct his/her sensory mechanism to search for particular types of information. As this search for information gathers additional information, the AL's expectations are modified accordingly. This means that when any given schema within the AL receives environmental input that is appropriate to it (i.e. when it is activated), it results in a set of perceptual expectations about what is likely to occur next. In other words, the perception of the patterns of information is based on prior knowledge, on what the learner expects to see, and on the concepts he/she understands that have been retrieved from his Long Term Memory (LTM) via the *feedback loop* (Johnstone, 1997) for the perception filter (see Fig.7). The concept of retrieval (which the Contiguity Hypothesis depicts as a form of connectionism) will be elaborated on in a later section. If an unexpected type of stimulation occurs (e.g. new and unfamiliar scientific phenomenon), the likelihood is that he/she will attempt to find out how it fits into the scheme of its prior learning. To make sense of the experience he/she mobilizes his cognitive schemata in order to restructure the new experience into a meaningful and interpretable format compatible with the worldview templates serving as a frame of reference for him/her. The African learner recalls, relates and compares information from his science classroom with that from his African worldview schemata as well as his/her commonsensical-intuitive knowledge to attain a form of *contiguity learning*. The activities and the resulting perceptions are normally transferred into what Ogunniyi (1986) calls 'the learner's library of knowledge' otherwise known as his/her Working Memory (WM).

Eggen and Kauchak (1994) have argued that perception is critical to the learning process because the information that will be eventually transferred to the working memory (WM) will be the African learner's perception of the scientific phenomena taken from his/her sensory registers. Hence, the information entering the WM may not necessarily be a form of literal reality, but his/her interpretation of reality, and consequent expectation. Thus if the African learner has misunderstood a given information about a phenomenon, what he/she holds in his/her working memory will be invalid, and ultimately, the information transferred to his/her Long Term Memory (LTM) will also be scientifically invalid. What is more, if the African learner has misinterpreted the incoming scientific phenomenon, he/she will develop misconceptions that may be hard to eliminate as they become embedded in a complex schema (Eggen and Kauchak, 1994)

Language, as part of the symbolic structures of the eco-social systems found in the AL's socio-cultural environment (shaded region in Fig.7), also plays a vital role in how the learner perceives the incoming information. According to Duran et al (1998), language systems include forms of talking and writing as well as diagrams and other symbolic means of constituting meaning. They argue that:

> Language mediates thinking by imparting meaning to action.... Learning a language mediates thinking by organizing our perceptions of reality in temporal, spatial, and causal concepts. Subsequently, language is used to regulate our actions in relation to those perceptions. Through individual internalisation of the experience, language and thought are shaped by culturally situated activity. Thus, understanding is a social behaviour before it is individual, and it is situated relatively with a social other before it is internalized (Duran et al., 1998: 314).

The "social other", to which Duran et al are referring to in the above statement, is the teacher relating to the AL within a classroom situation. This is similar to the "capable other" in Vygotsky's (1986) concept of Zone of Proximal Development (ZPD). According to Rollnick (2000), Vygotsky's concept of ZPD views the teacher as playing the vital role of the "capable other" who uses language as the mediator of the shared discourse between him/herself and the AL.

Lemke (1990) has described learning in high school science as a process of understanding the linguistic organization of context and acquiring the functional uses of science language in the classroom (a part of the eco-social environment in Fig.7). Furthermore, Fradd and Lee (1999) have noted that language proficiency and literacy are closely related to science learning. For instance, if the AL has little science knowledge and vocabulary, he/she will produce the least amount of language and will be least aware of how to use cognitive strategies. In addition, Rollnick (2000) argues that the issue of language poses as a double challenge to a second language learner such as the AL in that he/she "needs to learn both the social practices of the language and its place in the new social practice (he/she is) attempting to join, in this case, science" (p. 98). It is with this observation in mind that Eggen and Kauchak (1994) suggest that the teacher must constantly check to ascertain that the AL perceives his/her examples correctly, further demonstrating the view that learning as a situated cognition takes place within the learner's socio-cultural environment (Rollnick, 2000).

5.5.5 Working Memory (WM)

At this stage the perceived information from the sensory register is passed on to the working memory (WM). According to Johnstone (1997), the WM functions in two ways. Firstly, as the conscious part of the mind where the WM holds ideas and facts while thinking about them. In the second function, the WM serves as a shared holding and thinking space where the incoming information (e.g. a scientific worldview) from the perception filter consciously interacts with itself as well as with information retrieved from Long Term Memory (LTM). The latter, in the case of a learner in an African setting, would probably be a traditional worldview.

According to the Contiguity Learning Hypothesis, when the two or more worldviews lie contiguously, they interact with each other to form a sort of amalgam with the substratum of prior learning or what Ausubel (1968) calls subsumers, which in turn serve as an anchor for a new learning experience (see section 2.6.1). In terms of the Contiguity Learning Hypothesis, the worldviews come against each other and naturally seek points of contiguity (i.e. regions in the two thought systems sharing common elements) in order to accommodate, reconcile and adapt to each other. The learner's indigenous beliefs as well as his/her commonsensical-intuitive knowledge are contrasted with scientific concept encountered in the science classroom and given a tentative status. The concepts (from the science lesson and from LTM) now lie contiguously and information is then processed by recalling, relating, collaborating the new with the old knowledge. In another sense, the views also tend to compete, supplant and dominate one another in the learning process depending on the worldview template serving as a frame of reference in the given context. According to Ogunniyi (2002b), a given context triggers off the worldview schemata in the AL resulting in a corresponding worldview schema gaining dominance over the others within the AL's cognitive structure. The worldview here acts as a cultural Hegelian dialectic, which then transforms the apparently contradictory ideas to a higher form of understanding and consequently, *contiguity learning*. The success of this integrative and transformative cognitive process is what Ogunniyi (2000) calls contiguity learning. The level of success determines the type of border crossing that takes place, for example, hazardous, managed or impossible (see Aikenhead and Jegede, 1999). *Hazardous border crossing* would occur when the worldview schemata have gained more or less equal supremacy; *managed border crossing* would occur when the scientific worldview schema is dominant; and *impossible border crossing* when the traditional worldview schema is dominant. By the same token the process may result in certain forms of collateral learning, for example, parallel, secured, dependent or simultaneous (see Jegede, 1995).

Some *border crossing* (Aikenhead, 1996) starts to take place as the AL screens the scientific phenomenon and decides what to do with it. In this instance, according to Moates and Schumacher (1980), the WM serves as a kind of "information gate" where only about seven chunks of knowledge are stored and processed at one time. The chunk size depends on the amount of the related knowledge stored in the LTM, which mainly consists of the learner's dominant African worldview presuppositions most of which had been acquired in early childhood. The AL must possess some recognizable conceptual framework that enables him/her to draw on old, or systematized new, material. As indicated earlier, the types of border crossings to a large extent are dependent on the success or otherwise of the integrative mechanism responsible for harmonizing the clashing worldviews. As mentioned earlier in chapter 2, Aikenhead (1996) has identified the different types of border crossing that might result from interacting worldviews as follows:

- *Managed border crossing* occurs when the AL's acquires the incoming information in order to make it accessible to him/her whenever he/she needs to achieve such social goals as talking with his/her teacher or passing examinations, even though that knowledge may contradict or seem irrelevant to his/her traditional worldview.
- *Hazardous border crossing* occurs when the AL does not understand the incoming information because his/her worldview and the scientific worldview are rather diffused leading to hazardous transitions from one worldview to the other. The AL will be motivated to do as well as he/she can because he/she does not want to look stupid at school.
- *Impossible border crossing* occurs when the AL's worldview and that of science are highly discordant causing him/her to resist transitions from one worldview to the other.

As indicated earlier, the cognitive process involved in these categories of border crossing awaits further investigation and clearer articulation.

In general, and with respect to the above types of border crossing it is reasonable to suggest that the AL then builds his/her own knowledge from what is presented to him/her in class. He/she learns by reconstructing the new knowledge in a way meaningful to him/her. Learning becomes an idiosyncratic reconstruction of what the AL understands, or thinks he/she understands the new material provided, tempered by the existing knowledge, beliefs, biases, or misunderstanding. The ability to retrieve information from the LTM requires deep understanding of the subject matter, so that the information acquired can be used productively in novel environments. The

Fradd, S.H. and Lee, O. (1999). Teacherss' roles in promoting science inquiry with students from diverse language backgrounds. *Educational Researcher*, 8(6): 14-20.

Fraenkel, J.R. and Wallen, N.E. (1993). *How to Design and Evaluate Research in Education*. New York: McGraw Hill.

Garnett, M. (1980). *"Take Your Glory Lord" William Duma: His Life Story*. Roodeport: Baptist Publishing House.

Gay, L.R. (1981). *Educational Research: Competencies for Analysis and Application*. Columbus: Charles E. Merrill Publishing Company.

George, J. (1992). Scioence Teachers as Innovators Using Indigenous Resources. *International Journal of Science Education*, 14, 95-109.

George, J. (1999a). Contextualised Science Teaching in Developing Countries: Possibilities and Dilemmas. *Proceedings of the 7th Southern African Association of Research in Mathematics and Science Education*. Harare, Zimbabwe, 17 - 22.

George, J. (1999b). World View Analysis of Knowledge in a Rural Village: Implications for Science Education. *Science Education*, 83, 77-95.

George, J and Glasgow, J. (1988). Street Science and Conventional Science in the West Indies. *Studies in Science Education*, 15, 109-118.

Golding, H. and Osborne, J. (1994). Students' Difficulties with Energy and Related Concepts. *Physics Education*, 2, 26 –31

Good, R. and Shymansky, J. (2001). In Bevilacqui, F., Gianetto, E. and Matthews, M.R. *Science Education and Culture*. Dordretch: Kluwer Academic Publishers, 53-65.

Ehindero, O.J. (1982). The Effects of Eco Cultural Factors in Operational Thinking Among Some Nigerian Adolescents. *Journal of Research in Science Teaching*, 19(6), 451-457.

Ellerton, N. (1999). Language Factors Affecting the Learning of mathematics and Science: A Holistic Perspective. In M.A. Clements and L.Y. Pak (eds.) *Cultural and Language Aspects of Science, Mathematics and Technical Education*. Gadong: Universiti Brunei Darussalam, 59 – 68.

Emereole, H.U. (1998). Worldviews Portrayed by Illiterate Batswana Adults About Common Practices and Phenomena. *Journal of the Southern African Association for Research in Mathematics and Science Education*, 2(1), 41-51.

Emereole, H.U. and Ontse, B. (1995). Knowledge Of Concepts And Pricipples Of Sound Held By Illiterate Batswana. In A. Hendricks (ed.) *Proceedings of the Third Annual Meeting, Southern African Association of Research in Mathematics and Science Education, Cape Town:* Vol.1, 227- 237.

Emereole, H.U.; Munyadzwe, T.N.; Ntingana, C.M. and Mosimakoko-Mosalakgoko, T.B. (2001). Rationalisation and Science Instructional Implications of Some Superstitious Beliefs About Natural Phenomena in Botswana. *Journal of the Southern African Association for Research in Mathematics, Science and Technology Education*, 5, p53-54.

Fairbrother, R. (2000). Strategies for Learning. In M. Monk and J. Osborne (eds.) *Good Practice in Science Teaching: What Research has to say.* Buckingham: Open University Press.

Dewey, J. (1944). *Democracy and Education: An Introduction to the Philosophy f Education.* New York: The Free Press.

Dinie, S. (2000). *Investigating the Effectiveness of Concept Mapping in Improving Science Language Writing for English Second Language Grade 12 Learners at Lagunya Finishing School in Langa.* Unpublished Thesis. Cape Town: University of the Western Cape.

Driver, R. (1983). *Pupil as a Scientist*? Milton Keynes: Open University Press

Driver, R. and Erickson, G. (1983). Theories in Action: Some Theoretical and Empirical Issues in the Study of Students' Conceptual Frameworks in Science. *Studies in Science Education*, 10, 37-60

Driver, R and Oldham, V. (1986). A Constructivist Approach to Curriculum Development in Science. *Studies in Science Education,* 13, 105-122.

Driver, R.; Asoku, H.; Leach, J.; Mortimer, E and Scott, P. (1994). Constructing Scientific Knowledge in the Classroom. *Educational Researcher*, 23(7), 5-12

Driver, R. and Scott, P. (1995). Mind in Communication: A response to Erick Smith. *Educational Researcher*, 24(6), 27-28.

Duran, B.J.; Dugan, T. and Weffer, R. (1998). Language Minority Students in High School: The Role of Language in Learning Biology Concepts. *Science Education*, (82): 311-341

Ebenezer, J.V and Connor, S. (1998). *Learning to Teach Science*. Columbus: Merrill Prentice Hall.

Eggen, P. and Kauchak, D. (1994). *Educational Psychology: Classroom Connections.* New York: McMillan College Publishing Company.

Cobern, W.W. (1993). College Students' Conceptualizations of Nature: An Interpretive Worldview Analysis. *Journal of Research in Science Teaching*, 30(8), 935-951

Cobern, W.W. (1994). *Thinking about alternative constructions of Science and Science Education.* A plenary presentation for SAARMSE, 62-81

Cobern, W.W. (1996a). Constructivism and Non- Western Science Education Research. *International Journal of Science Education*, 18(3). 295-310

Cobern, W. (1996b). World-view Theory and Conceptual Change in Education. *Science Education*, 80(5), 579-610.

Cohen, L and Manion, L (1980). *Research methods in Education.* London: Croom Helm

Cohen, L.; Manion, L. and Morrison, K. (2000). *Research Methods in Education.* London: Routledge Falmer

Contreras, A. and Lee, O. (1990). Differential Treatment of Students by Middle School Teachers: Unintended Cultural Bias. *Science Education*, 74, 433-444.

Costa, V.B. (1995). When Science is "Another World": Relationship between Worlds of Family, Friends, School, and Science. *Science Education*, 79(3), 313-333.

Davis, S.H. and Ebbe, K (1995). *Traditional Knowledge and Sustainable Development.* Proceedings of a Conference held at The World Bank, Washington, D.C., 7 – 42.

Dembo, M. H. (1982). *Teaching for Learning: Applying Educational Psychology in the Classroom.* Glenview: Scott, Foresman and Company.

Beaumont-Walters, Y and Soyibo, K. (2001). An Analysis Of High School Students' Performance On Five Intergrated Science Processes. *Research and Technological Education*, 19 (2), p133-146.

Boyle, C. and Williams, S. (1991). *Core Physics for A-Levels Set A: Mechanics.* Cambridge: Daniels Publishing.

Brandt, L.; Elen, J.; Hellemans, J.; Heerman, L.; Couwenberg, I.; Volckaraert, L. and Morisse, H. (2001). The Impact of Concept Mapping and Visualization on the Learning of Secondary School Chemistry Students. *International Journal of Science Education*, 23(12), 1303-1313.

Byron, J. (1992). GSCE Steps in Physics. Oxford University Press.

Cobern, W.W. (1993). College Students' Conceptualization of Nature: an Interpretive Worldview. Analysis. *Journal of Research in Science Teaching*, 30(8), 935-951.

Catsambis, S. (1995). Gender, Race, Ethnicity, and Science Education. *Journal of Research in Science Teaching*, 32(3), 243- 257.

Chambers, S.K. and Andre, T. (1997). Gender, Prior Knowledge, Interest, and Experience in Electricity and Conceptual Change Text Manipulations in Learning About Direct Current. *Journal of Research in Science Teaching*, 34(2), 107 – 123.

Chomsky, N. (2000). *New Horizons in the Study of Language and Mind.* Cambridge: Cambridge University Press

Cobb, P. (1994). Where is the Mind? Constructivist and Sociocultural Perspectives on Mathematical Development. *Educational Researcher*, 23(7), 13 – 20.

Cobb, P. (1995). Continuing the Conversation: A Response to Smith. *Educational Researcher*, 24(6), 25-27

Allen, N.J. and Crawley, F.E. (1998). Views from the Bridge: Worldview conflicts of Kickopoo Students of Science. *Journal of Research in Science Teaching*. 35(2), 111-132.

Ashman, A. and Conway, R. (1993). *Using Cognitive Methods in the Classroom*. London: Routledge.

Atwater, M.M. (1996). Social Constructivism: Infusion into the Multicultural Science Education Research Agenda. *Journal of Research in Science Teaching*, 33, 821-837.

Ault, C.R. (1985). Concept Mapping as a Study Strategy in Earth Science. *Journal of College Science Teaching*, 15, 38-45

Austin, C.B. and Shore, B.M. (1995). Using Concept Mapping for Assessment in Physics. *Physics Education*, 36(1), 41-45.

Ausubel, D.P. (1968). *Educational Psychology*. New York : Holt, Rinehart and Winston.

Avison, J. (1989). *The World of Physics*. Hong Kong: Nelson.

Baker, D. And Taylor, P.C.S. (1995). The Effect of Culture on the Learning of Science in Non-Western Countries: the Results of an Integrated Research Review. *International Journal of Science Education*. 17(6), 695-704

Bandiera, M.; Neves, M.C.D. and Vicentini, M. (1999). Nature of World View Pre-suppositions Among Science Teachers in Italy and Brazil. *Acta Scientiarum*, 21 (1), 97-106

Barba, R.H. (1993). A Study of Culturally Syntotic Variables in the Bilingual/bicultural Science Classrooms. *Journal of Research in Science Teaching*, 30, 1053-1071.

LIST OF REFERENCES

Adams, S. (1999). An Analysis of Border Crossing Between Learners' Life Worlds and School Science. *Journal of the Southern African Association for Research in Mathematics and Science*. 3(1), 14-21.

Adamcyzk, P; Willson, M and Williams, D (1994). Concept Mapping: A Multilevel and Multipurpose Tool. *School Science Review*, 76(275), 116-24.

Adeyinka, O.J.; Kyeleve, J.I. and Yandil, C.D. (1999). Superstitions among Batswana: Implications for Science teaching. *Proceedings for the Conference on Mathematics, Science and Technology Education in the Next Millenium.* National University of Lesotho, Roma, 128 - 142.

Aikenhead, G. (1996). Science Education: Border Crossing into the Sub-culture of Science. *Studies in Science Education*, 27, 1-57.

Aikenhead, G.S. (1997). Towards a First Nations Cross-Cultural Science and Technology Curriculum. *Science Education*, 81, 217-233.

Aikenhead, G. (1999). *Barriers to Accommodating Culture in The Classrooms.* Paper presented at the 9th Symposium of the International Organization for Science and Technology

Aikenhead, G. (2000). Renegotiating the Culture of School Science. In R. Millar, J. Leach and J. Osborne (eds). *Improving Science Education: The Contribution of Research.* Buckingham: Open University Press.

Aikenhead, G. and Jegede, O.J. (1999). Cross-Cultural Science Education: a Cognitive Explanation of a Cultural Phenomena. *Journal of Research in Science Teaching*, 36 (3), 269-287

Cobb, 1994)?

- Are mental processes caused by certain physico-chemical elements and metaphysical schemata in the brain or not (Ogunniyi, 2002b)?

All the above questions show the complexity of the mind-body controversy, which, unfortunately, is beyond the scope of this study.

6.4 CONCLUDING NOTE

As far as the researcher is aware, there is no study in Swaziland specifically concerned with determining the nature of the learners' worldviews and how such views result in different forms of cognitive border crossing from the traditional to the scientific worldview. Likewise, she is not aware of any study specifically concerned with the improvement of science teaching-learning process using the cultural approach and concept mapping instructional strategies. This study has revealed that the use of the latter can enhance the learners' understanding of the concepts of force, energy, work and power. However, the potential of the instructional strategies adopted in this study are worthy of closer consideration in future studies using larger samples and involving a longer duration to provide a more holistic analysis of learners' worldviews, border crossings and conceptions.

also practice border crossing as they teach? If so, what kind of model would be needed to depict the teachers' cognitive navigation from one worldview to another? Would the three constructs of Border Crossing (Aikenhead, 1996), Collateral Learning Theory (Jegede, 1995), and Contiguity Learning Hypothesis (Ogunniyi, 1995, 2002b), be applicable in the case of teachers, or would they need some modification?

Needless to say, that further investigation and clearer articulation is still needed for the cognitive process involved in the various categories of border crossing. Besides, in view of the findings, so far, the suggestion by Ogunniyi (2002b) that the process of cognitive border crossing involves physiological, psychological and metaphysical phenomena as proposed by the Contiguity Learning Hypothesis requires empirical confirmation. Certainly further studies are needed to determine this proposition as well as the specific conditions responsible for the process of border crossing from a traditional to a scientific worldview besides those laid out by the African Learner Model, which was proposed by the present study.

Also, it is apposite to state that the information-processing model depicted in the African Learner Model was found to be only an aspect of a more complex mechanism that needs further interrogation. Further investigation is still needed to find more information about the human mind. For instance:

- Can the human mind be equated to a digital computer or computerized programme as the information processing models seem to suggest (See Searle, 1984; Moore, 1998)?
- Is the mind located in the brain or elsewhere in the body (see Szasz, 1996;

there were, the failure to achieve significant change, or achieve in this case a smooth border crossing (Aikenhead and Jegede, 1999), has demonstrated the complexity of the task as well as generated greater respect and appreciation on the part of the researcher for the difficult work that teachers need to do to achieve such an outcome. Further investigation is needed to come up with better solutions to the issue. Some of the issues that need further research are highlighted in the sub-section that follows;

6.3.3 Research Implications

The results of the study also imply that further research is needed to explore teaching strategies that can be used in the science classroom to effect border crossing on other topics besides force, energy, work and power. Besides, such investigations would have to be carried over longer periods, using bigger samples in order to come up with generalisations. The following are some of the questions that could be addressed:

- Should the aim of teaching strategies be to replace worldviews held by the learners or not?
- Are different types of border crossing strategies needed for different types of cultural background knowledge?
- What is the nature of the cognitive structures or mentality of learners living in traditional societies?

In addition, research is also needed to investigate teachers' views and attitudes towards learners' cultural backgrounds and towards proposed culturally sensitive instructional strategies considering the fact that the teachers themselves are also products of their cultural backgrounds (George, 1999a). What effects do these attitudes when present have on the teaching/learning environment? Do the teachers assumes the role of a facilitator in evoking conceptual conflict on the one hand and integrative conceptual reconciliation on the other (Ogunniyi, 2002b)

- The instructional strategies should include the use of concept mapping in order to facilitate meaningful learning (Adamcyzk et al., 1994; Ebenezer and Connor, 1998; Novak, 1990) as was done in this study. This tool could encourage the learners to look for a relationship between what has been presented in class and other information already stored in their long-term memory. Conscious attempt should be made to relate the daily occurrences in the learners' immediate environment to the learning experiences in the science classroom. This would require the teachers to contextualize instructional materials in such a way that links science lessons to the learners' everyday experiences (Ninnes, 2000; Kawagley et al., 1998; Matthew and Smith, 1994) as was illustrated by the findings of this study. As mentioned earlier, the study used the concept map to help the subjects to make meaningful connections between the science concepts learned in the science lessons and the natural phenomena found in their immediate surroundings.

As in many previous studies (Solomon, 2001; Tesfai, 2001; Lubben, Netshisaulu and Campbell, 1999), in spite of the rigour and care taken to develop and implement a well-structured exemplary instructional material, the approach has not proved superior to traditional instruction in terms of ameliorating the subjects' alternative conceptions. In other words, the alternative notions about the concepts have persisted even after the instructional intervention (see Gunstone and White, 2000). Whatever other outcomes lesson in order to reach consensus on the terms and concepts used to explain natural phenomena (Lawrenz and Gray, 1995). He/she should act as a facilitator and encourage the learners to talk about how what they hear from science compares with what they believe from their socio-cultural environment. The learners must be actively involved, practicing and checking the utility of their views and receiving feedback in the process (Eggen and Kauchak, 1994; Proper, Wideen and Ivany, 1988). For example, teachers should encourage open discussions to allow alternative conceptions to manifest in order to determine how to expose the learners to scientifically valid conceptions about various natural phenomena (Sutherland and Dennick, 2002; Cobern, 1993; Jegede and Okebukola, 1999a and b). The results of this study attested to this. The subjects involved in the videotaped group discussion spoke freely about their views concerning some natural phenomena found in their socio-cultural environment, hence enabling the researcher to identify their alternative conceptions. This would also help the learners to explore the differences and similarities between their cultural beliefs and the science concepts they have learned in class (Snively and Corsiglia, 2001)

- Highlight the relationship he/she wants the learners to learn by guiding their understanding of the context of his/her lesson. Also, by developing open-ended questions based on the learners' responses and moving forward only when the relationship makes sense to the learners (Eggen and Kauchak, 1994) the teacher teaching/learning environment of traditional societies.

6.3.2 Instructional Implications

Judging from the envisaged improvement in the performance of the experimental (E) and second control group (C_2) that were involved in this study, and based on the assumption that it was due to the exemplary instructional strategies, it would seem viable to point out the following implications:

- Science teachers need to use a socio-cultural mode of instruction that incorporates indigenous knowledge and the alternative worldviews held by the learners, and/ or found in the socio-cultural environment of the school in order for the teaching/learning situation in science to make it possible for learners in traditional settings to have easier access to science. This study used this approach as an intervention in the experimental and second control groups (E and C_2). Several examples from the subjects' socio-cultural environment were used to illustrate some of the concepts of force, energy, work and power, and the subjects were also encouraged to come up with their own examples. Also, the results of the PAT show that the subjects in E and C_2 performed well on the questions (e.g. Q1.2 in which the subjects got mean percentages of 90% - 92%) that required them to provide examples For this socio-cultural mode of instruction to be successful, the teachers could:
    - Begin by ascertaining the nature of the learners' worldviews cultural perspectives and other metaphysical concepts found in their socio-cultural environment (Okebukola and Jegede, 1990; Jegede and Okebukola, 1991a and b; George, 1999a and b).
    - Increase the amount of discussions that take place during each

White (2000) have proposed a co-existence approach where the learners are not made to abandon their cultural background knowledge for conventional science, but instead are encouraged to adjoin the two worldviews. Some of the subjects of this study did vent their feelings concerning this issue. They argued that education was not supposed to "change" their cultural beliefs. In this regard, Gunstone and White (2000) have further argued that it should be left to the learner to discern when and under what conditions it is appropriate to apply one worldview or the other. In addition, Jenkins (2000) has argued that:

> The notion that students, and, more generally, adults, should always explain natural phenomena in terms that accord fully with the canon of scientific knowledge presents problems.... Moreover, as public understanding of science has revealed, the seemingly straightforward 'application' of scientific knowledge in the world far removed from the laboratory can sometimes be misleading and unhelpful and there may be good reasons for its rejection in favour of other, more local or personal knowledge and understanding. Even among those with a scientific background, outdated scientific ideas may still be used because they adequately serve the purpose in hand (p.160)

The subjects of this study demonstrated this by exhibiting different worldview presuppositions under different contextual circumstances. The Contiguity Learning Hypothesis (Ogunniyi, 2002b) described this in terms of the influence of a dominating worldview context and the human interest being served. The question is, do science curriculum planners see these contextual issues to be critical to the content of the curriculum or do they see science only in terms of its universality? This question warrants a closer attention in future studies.

Whatever curriculum package may be decided on, it will not be effective unless implemented in the science classroom. The next section will discuss the implications of the findings on instructional strategies that may be employed in the worldview presented in the science classroom. The study also described how the three theories/hypotheses could be combined to form the so-called African Learner Model, which is an attempt to depict the process of border crossing within an African setting.

George (1999b) has observed that teachers in non-western contexts are faced with the challenge of their personal attitudes towards the learners' cultural background knowledge. She argues that teachers with negative attitudes will, more than likely,

> Persist with a conceptual change approach to science teaching, with the emphasis being on getting learners to rid themselves of cultural background knowledge and replace this with conventional school science (George, 1999b: 21).

Ogunniyi et al. (1995) have also argued that it is important for teachers to understand the learners' fundamental, culturally based beliefs so as to teach a kind of science that coincides with the intellectual interest and socio-cultural setting of such learners. This implies that teachers and curriculum developers in non-western contexts would need to be equipped through pre-service and in-service programmes with instructional strategies that will help them present science to learners in a way that would take into account the learners' cultural beliefs (George, 1999b; Contreras and Lee, 1990; Proper et al., 1988).

Kyle (2002) has argued that neglecting the content and processes of an indigenous culture is likely to lead to what he calls 'assimilationist curriculum'. Several studies (Allen and Crawley, 1998; Lowe, 1995; Kawagley et al., 1998) have shown that a curriculum that is not sensitive to the learners' cultural background tends to produce passive learners. To alleviate the consequences of such a curriculum, Gunstone and

- The identification and use of fundamental scientific and technological principles, theories and concepts of indigenous practices within the African societies
- The teaching of the values of the typical African humane feelings in relation to, and in the practice of technology (Jegede and Okebukola, 1991b).

Ogunniyi et al. (1995) have added that such an explicitly culturally sensitive curriculum would enlighten the learner about the meaning and values of his/her experiences with natural phenomena. The findings of this study revealed that such an approach is feasible. The intervention used in the study on the experimental and second control groups (E and C_2) yielded positive results in their performance on the PAT. These groups obtained higher overall means than their counterparts who were not exposed to the intervention. Despite these positive results, however, it must be conceded that the best way to integrate learners' indigenous knowledge with school science requires a more in-depth analysis and long-term endeavour than has been done in this study.

A science curriculum using the above mentioned suggestions would require a science education perspective that views science learning as a process of crossing the boundary between the learners' worldview and science worldview (George, 1999b) as has been illustrated in the results of this study. As mentioned earlier, several theories/hypotheses have been proposed in this regard. This study has illustrated how three of such theories/hypotheses (Border Crossing Theory, Collateral Learning Theory, and Contiguity Learning Hypothesis) can be used not only to identify, but to also describe a learners' border crossing from an alternative worldview to a scientific

Crawley, 1998; Jegede and Okebukola, 1991 a and b; Okebukola and Jegede, 1990). The results of Physics Achievement Test (PAT) and the videotaped group discussions revealed some alternative conceptions on the concepts of force, energy, work and power. It can be assumed that based on the results of the MIAN and the videotaped group discussions, that these alternative conceptions might have been arisen from the subjects' traditional worldviews, which are the product of their socio-cultural environment. To alleviate the effect of these alternative conceptions, Allen and Crawley (1998) have suggested that:

> By examining the way in which the scientific ways of thinking and acting are integrated into other beliefs, science educators may more successfully separate ways of thinking and acting which are essential to the nature and practice of science from those which are cultural artefacts that may hinder science learning. (p.129)

Jegede and Okebukola (1991b) have pointed out the need for curriculum developers "to recognize the role that instruction through the socio-cultural mode might play in the development of positive attitudes towards the learning of science in traditional societies" (p.282). Several educators (e.g. Proper, Wideen and Ivany, 1988; Okebukola and Jegede, 1990; Jegede and Okebukola 1991a and b; Allen and Crawly, 1998; Kawagley et al., 1998) have even proposed the integration of indigenous knowledge held by learners with the science curriculum in a way that learners see science as a human enterprise not as an esoteric subject to be encountered only in the school environment. Jegede and Okebukola's (1991b) have argued further that, in order to be meaningful, such curricular materials should include:

- Copious examples of the African way of interpreting various natural phenomenon type of collateral learning that would take place in a learners' Long Term Memory. For instance:

- Hazardous border crossing would lead to dependent collateral learning
- Managed border crossing to either parallel or secured collateral learning
- Impossible border crossing without any collateral learning occurring.

The so called "African Learner Model" also attempted to show that apart from what the three models depict, cognitive border crossing is also the product of cognitive conflict resolution engaged in by an individual through the instrumentation of language and situated cognition.

Needless to say, the above findings have various implications for science education, which will be discussed in the following sub-sections.

6.3 IMPLICATIONS OF THE FINDINGS

Some important curricular, instructional and research implications arising from the findings of the study are presented in the subsequent subsections.

6.3.1 Curricular Implications

Several science educators (e.g. Sutherland and Dennick, 2002; George, 1999b; Lynch, 1996 a and b) have noted the influence of worldviews held by teachers and learners on the teaching and learning of science. It has been discovered that these worldviews sometimes have the tendency to impede the conception of science concepts, as has been the case with some of the subjects of this study (Allen and capture the process when treated separately. Therefore, the African Learner Model was proposed, which combines the three theoretical models: Aikenhead's (1996) Border Crossing; Jegede's (1995) Collateral Learning, and Ogunniyi's (1995) Contiguity Learning to show how, when, and under what conditions the various types of border crossings and collateral learning might occur within the mind of a learner living in an African socio-cultural context. According to Ogunniyi (2000), during the contiguity learning process, the information received or the condition evoked by a given experience tends to arouse a given worldview schema in the working memory to trigger off the assemblage of certain appropriate elements (e.g. neurotransmitters) in each macro-thought or schema capable of responding to the changed mental state to attain one of the following border-crossing intellectual postures:

- Managed border crossing; a case where the scientific worldview schema is dominant
- Impossible border crossing; a case where the traditional worldview schema is dominant.
- Hazardous border crossing; a case where the contiguous worldview schemata are at equilibrium (i.e., none of the schemata is dominant but all three are evident) or where the commonsense-intuitive schema is dominant

According to Ogunniyi (2002b), it is the quality or strength of the experience, which predisposes a learner to exhibit a particular type of border-crossing mentality. The resultant type of border crossings would then determine the considered because the subjects' life worlds were not found to be congruent with that of school science.

- Jegede and Aikenhead's (1999) proposed relationship between types of collateral learning and border crossing: parallel learning and managed border crossing; secured collateral learning and managed border crossing, and dependent collateral learning and hazardous border crossing, were also demonstrated in the subjects' video discussions on a few selected natural phenomena.
- The Contiguity Learning Hypothesis (Ogunniyi, 1995) was also applicable to the subjects' traditional worldview presuppositions concerning selected natural phenomena held in their socio-cultural environment. The video discussion showed copious instances of how a certain dominant worldview context could trigger off a variety of worldview schemata viz: the mobilization of the traditional worldview schema or a combination of these depending on the human interest in vogue. Ogunniyi (1988, 2000) has argued that each of these schemata contains some elements of the other two, which can be mobilized to reinforce a particular worldview once a given threshold has been reached. He calls the mobilization of these schemata to achieve an integrative and transformative mental stage a contiguity learning process. According to Ogunniyi (2000), the level of success in reaching this state of mental harmony or equilibrium would determine the type of border crossing that occurs.

- In Section 5.5, it was observed that each of these constructs could not fully

- As indicated in Section 4.5.3, the results suggested that the subjects' interest in science does have an influence in their conception of force, energy, work and power. The t-values for the true control group (C_1) and second control group (C_2) (i.e. the group denied the pre-test), indicate that there was a significant difference in the performances of the subjects that had a high interest in science and those that had a low interest whereas there was no such significant difference in the experimental group (E) between the interest sub-groups. The subjects with a high interest in science in C_2 got the highest mean score (27.44), followed by the subjects in C_1 (20.67) and lastly those in E with a mean score of 19.91. The low interest group in C_2 got the highest mean (21.57), followed by the group in E (19.80), and lastly those in C_1 (12.50). Overall, high interest group in C_2 got the highest mean scores while the low interest group in C_1 got the lowest mean scores.

- As indicated in Chapter 4, the results of the study have demonstrated that the Border Crossing Theory, Collateral Learning Theory and the Contiguity Learning Hypothesis could not be falsified by the findings i.e., the explanatory models seem applicable to the subjects' traditional and scientific worldviews with respect to selected natural phenomena, though in varying degrees. The analysis of the results revealed sufficient evidence of different forms of cognitive border crossing depicted by the three learning theories/hypothesis.
    - Aikenhead's (1996) types of border crossings: managed border crossing, hazardous border crossing and impossible border crossing were demonstrated in the subjects' presuppositions about the concepts of force, energy, work and power. Smooth border crossing was not

force, energy, work and power while the performance of the males in group C_2 ($t = 0.63$) was not significantly different from their female counterparts. However, the males got higher means than the females in all three groups. The males in E had a mean of 21.38 and a standard deviation of 6.51 while the females had a mean of 18.38 with a standard deviation of 6.47. Similarly, the males in C_1 got a mean of 22.17 and a standard deviation of 6.81 as compared to the females who got a mean of 14.38 with a standard deviation of 4.02. The males in C_2 also outperformed the females with respect to their conception of force, energy, work and power; their mean score being 27.34 with a standard deviation of 7.90 compared to a mean of 26.11 and a standard deviation of 3.54 for their female counterparts. Overall, the males in C_2 got the highest mean while the females in C_1 got the lowest mean.

- With respect to age the post-test results showed that the under-seventeen year olds in E got the highest mean scores while the seventeen year olds got the lowest mean in the group. The nineteen year olds in C_1 got the highest mean scores while the seventeen year olds got the lowest mean scores. The under-seventeen year olds in C_2 got the highest mean scores while the nineteen year olds got the lowest. However, the F-values within the three groups in the post-test reveal no significant differences on account of age suggesting that that age does not have a significant influence on the subjects' performance with respect to the concepts of force, energy, work and power. Overall, the under-seventeen year olds in C_2 got the highest mean while the eighteen year olds in C_1 got the lowest mean.

that they responded in a random way since one can identify certain patterns in their comments. For example, with the exception of their responses to items dealing with science, magic and mysticism, the disagreement percentages were much higher than the agreement percentages on all the other worldview presuppositions. The disagreement percentages in a descending order were on spiritism, metaphysics, parapsychology, pseudo-science, rationalism, science and lastly magic and mysticism. The metaphysics, parapsychology, and pseudo-science category attracted the highest percentage of indecision among the subjects with respect to the alternative response choices.

- As indicated in Section 4.4.1, the two groups: the experimental (E) and second control group (C_2), which had an intervention performed better than the true control group (C_1), which was not so exposed to the treatment constituting the intervention. The ANOVA results of the post-test scores for all the three groups showed that the F ratio (13.17) is greater than the critical F-value of 3.07 suggesting significant differences among the groups with respect to their conceptions of force, energy, work and power. However, the significant difference was revealed by the Scheffe's test and a grand mean difference to have been between the second control group (C_1) and the others (E and C_1), and not between the pre-tested groups (E and C_1).

- As indicated in Section 4.5.1, the subjects' conceptions of force, energy work and power seemed to be influenced by their sex. The values for the t-test show that the males in group E ($t = 1.69$) and C_1 ($t = 4.66$) performed significantly better than their female counterparts at $p < 0.05$ on the topic of

CHAPTER SIX

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

6.1 OVERVIEW OF THE STUDY

The study attempted to: (1) identify the subjects' conceptions (i.e. indigenous and scientific knowledge) of selected natural phenomena viz: force, work, energy and power; (2) explore the subjects' explanations of selected experiences with natural phenomena; (3) analyse the nature of the subjects' explanations of selected traditional practices found in their socio-cultural environment; and (4) determine the applicability or otherwise of certain cognitive theories/hypotheses to the subjects' traditional and scientific worldviews with respect to the selected natural phenomena. In addition, the study attempted to determine the effect of concept mapping and certain cultural experiences in the instructional materials on the subjects' conceptions of selected natural phenomena. The hope was that such enriched learning materials derived from the subjects' immediate daily experiences would enhance their understanding of the phenomena in question as well as provide useful information about the way learners in non-western environments undergo border crossing between their traditional worldviews and that of science. The major findings in this regard are presented in the sections that follow.

6.2 MAJOR FINDINGS OF THE STUDY

- As indicated in Section 4.3, it was found that the subjects of this study, regardless of their gender, age and interest in science, hold a multiplicity of worldview presuppositions. However, their conceptions of various natural phenomena appeared to be disparate and inconsistent. This does not imply highlighted. It was noted that some writers (e.g. Szasz, 1996; Searle, 1984) have cautioned about the notion of equating the human mind to a digital computer, which they claim is the case with the information-processing model. Needless to say, the subject of the human mind still requires further interrogation. A much-detailed summary of the findings and some of the salient implications for future consideration will be highlighted in the following last chapter.

Contiguity Learning Hypothesis (Ogunniyi, 1995), on the other hand, attempted to use physiological, psychological and philosophical explanations that depict the phenomenon of border crossing as a dynamic rather than a fixed process. It proposed that the process of border crossing depends on the context and interest being served.

The study also observed that the three constructs did not include the issue of language despite the fact that literature (e.g. Tobin, 1996; Lemke, 1990; Rollnick, 2000; Duran et al., 1998) has pointed out its importance in the teaching and learning of science. As a matter of fact, the learning of school science has been described as a process of understanding the linguistic organization of context and acquiring the functional uses of science language in the classroom (Lemke, 1990).

The last section of the chapter was dedicated to discussing the African Learner model proposed by the researcher to not only describe how an African Learner crosses the border between his/her traditional worldview and the scientific worldview, but also illustrate how and under what conditions the African Learner acquires the different types of border crossing and collateral learning he/she displays. The African Learner Model illustrated how the three theories/hypotheses of border crossing, collateral learning and contiguity learning could be combined and integrated into the information processing model to describe how a learner in an African setting acquires and stores information presented in the science class. It is hoped that in future studies the veracity or otherwise of the bold propositions made by the African Learner model will be empirically tested using the findings of this study as well as data from other larger samples taken over longer periods. Current debates about the information-processing model as well as the function and definition of the mind were also

- Science teachers ought to eradicate these traditional beliefs and substitute them with valid scientific views and concepts.

The effectiveness of instructional strategies that make use of the concept map as a tool for meaningful learning as well as integrate the learners' traditional worldview presuppositions into science lessons was highlighted. It was observed that the intervention that used these instructional strategies had brought improvement in the subjects' conceptions of force, energy, work and power in that they obtained higher means compared to their counterparts who had not undergone the intervention.

Both the quantitative data from the PAT and the qualitative data from the videotaped group discussions indicated that the subjects did make use of border crossing both collaterally and contiguously. Also, the analysis on the PAT and fictitious stories confirmed the aptness of the three selected theoretical constructs for analysing the subjects' responses. Aikenhead's (1996) types of border crossings (i.e. managed, hazardous and impossible border crossings) were demonstrated. Jegede and Aikenhead's (1995) proposed relationships between types of collateral learning and types of border crossings, such as: managed border crossing and parallel or secured collateral learning; hazardous border crossing and dependent collateral learning; were also illustrated. However, it was observed that other than identify the different types of border crossing, the two theories of border crossing (Aikenhead, 1996) and collateral learning (Jegede, 1995) only provided ways of identifying and/or describing incidents of border crossing and not how such a process occurs. The constructs only managed to come up with fixed categories that left no room for the learners to navigate from one type of border crossing/ collateral learning to the other. The information; (b) give it a tentative status, and then either (c) alter it by reconstructing it under the influence of the incoming schema, or (d) reject it and replace it by a newly constructed schema (see Chapter 2).

If there were no matches that took place between the contiguous thought systems as they lay in the WM, resulting in the AL experiencing an *impossible border crossing* (Aikenhead, 1996), the incoming information would then be rejected. In other words, there would be no fit because the AL would have failed to attach the incoming information to the existing knowledge. *No collateral learning* would take place in this case, i.e., the African Learner would stick to his/her traditional worldview presuppositions regarding that particular phenomenon.

5.6 CONCLUSION

Chapter 5 has been a discussion of certain issues that emerged during the data analysis such as alternative worldviews, language, instructional strategies, and the applicability of the theories/hypotheses. The subjects' alternative worldview presuppositions were clearly illustrated in their responses to: (1) the MIAN; (2) questions 2.2, 2.3, 9.6 and 9.7 of the PAT; and (3) two fictitious stories based on some traditional practices in their socio-cultural environment. An analysis of the subjects' responses to the MIAN revealed the multiplicity of their worldviews. Some questions were raised as to whether or not:

- The learners' traditional worldviews were significant enough to be integrated into the school science curriculum seeing that some science educators still regarded them as superstitions and not scientifically valid (e.g. Adeyinka et al. 1999; Emereole et al., 2001) to conflict, or else he/she will achieve a convergence toward commonality by one schema enforcing the other, resulting in a new conception in the LTM, i.e. the AL will be able to resolve the conflict between the two or more schemata by actively considering all schemata and coming up with good reasons for holding on all of them (see Chapter 2).

If a unique situation occurs in which a concept learned by the African child in one domain of knowledge or culture facilitates the learning of a similar or related concept in another domain, *simultaneous collateral learning* (Jegede, 1995) will occur and the sets of schemata will be established in the LTM. It is possible that over time the African learner might retrieve the sets established by *simultaneous collateral learning* from his/her LTM in which case he/she will either further compartmentalize the schemata, a process leading to *parallel collateral learning*; or interact the schemata and resolve them in some way, a process resulting in either *dependent* or *secured collateral learning* (Jegede, 1995).

If a *hazardous border crossing* (Aikenhead, 1996) took place in the WM, the incoming encoded information will find at least a reasonable fit with the existing knowledge. In other words, the contiguous thought systems would match partially, possibly resulting in a misfit. The AL will experience *dependent collateral learning* meaning that the schema from one worldview will challenge the one from the other worldview such that the AL modifies the existing schema without radically restructuring the existing worldview (Aikenhead and Jegede, 1999). The AL will be unaware all this time that he/she is moving from one worldview to the other. He/she will: (a) contrast the information that is already in the LTM with the incoming contiguity (i.e. they will share common elements), and the incoming information will be merged into the LTM in order to enrich the existing knowledge and understanding. At this stage, at least two things can happen to the incoming scientific information:

- It can be held side by side with the conflicting traditional information without any interaction between the two: a case of *parallel collateral learning* (Jegede, 1995). When the incoming information reaches the LTM and the African learner experiences no visible disequilibria, that is, no confusion or surprise except to readjust his/her LTM to accommodate the different view presented in the science class, he/she has undergone *parallel collateral learning*. He/she has simply allowed the new information to coexist in his/her schemata while trying to make sense of the ideas that have been presented. On the other hand, the African learner might add meaning to the newly acquired information by connecting one bit of information with other associations or with existing indigenous knowledge in his/her LTM. The new information will be incorporated into prepositional networks and schemata (a process called elaboration). Certain aspects of the physical and emotional context of the material will be learned along with the information and become part of the prepositional network. In this way knowledge will occur through gradual and incremental acquisition. The African learner will endeavour to resolve the cognitive conflict, mental perturbation or dissonance that has occurred in the knowledge base held in his/her LTM;
- **OR** the incoming information can be understood, interacted consciously, and held together with the traditional worldview resulting in *secured collateral learning* (Jegede, 1995). The AL will develop a satisfactory reason for holding on to the two or more schemata even though the schemata may appear

new file is created and coded in some way for future retrieval.

The AL has learned meaningfully if he/she has a number of connections, or associations, between one idea and other ideas in his/her LTM. Ebenezer and Connor (1998) define meaningful learning as learning that is: (1) Non-arbitrary, a case where the AL chooses to fit or relate new knowledge into his/her existing cognitive structure; (2) Substantive, the learning that occurs when the AL makes a conscious effort to identify key concepts for new knowledge such as in everyday materials; and (3) Non-verbatim, occurs when the AL considers the individual or combined meaning of each word in a definition, and is a product of non-arbitrary and substantive learning. Eggen and Kauchak (1994) suggest that the teacher can help the AL by presenting relationships among ideas to help develop complex networks and schemata as well as connecting new ideas to previous learning.

5.5.6.2 Storing information in the LTM

Johnstone (1997) argues that at least three things can happen to the incoming information: it can find a good fit to knowledge already existing in the LTM; it can find a reasonable fit to the existing knowledge with a possibility of a misfit; or it cannot find a fit at all, resulting in its rejection. The way the incoming encoded information will be stored in the LTM, will depend on the types of border crossings that took place in the WM.

If *managed border crossing* (Aikenhead, 1996) took place between the contiguous thought systems in the WM, the incoming encoded information will find a good fit to existing knowledge in the LTM. In other words, the worldviews will find a point of schemata are, the more links exist for new information to be attached, and the greater an individual's capacity for further learning" (p. 317).

The encoding process depends on the type of *border crossing* (Aikenhead, 1996) that took place in the WM. It can be assumed that the type of border crossing will determine to a large extent how the information is encoded and finally stored in the LTM. If the incoming information can be linked to: (1) a reasonable number of networks already in existence in the LTM, the border crossing in the WM could be regarded *manageable*; (2) only to a few networks, the border crossing might be termed *hazardous* resulting in misconceptions and/or alternative conceptions; and (3) none of the networks, the border crossing would probably be *impossible*. However, despite this conjecture, it must be conceded that much still needs to be done to unravel the whole mechanism of border crossing. For instance, the success or otherwise of hooking up of incoming information with the networks and schemata or what Ausubel (1968) calls subsumers in the LTM presumably depends on the availability of contiguous sites, state or condition for such an anchorage (Ogunniyi, 2002b).

Eggen and Kauchak (1994) define retrieval as the process of accessing information from the LTM and view forgetting as a failure of retrieval. Retrieval becomes proficient if the encoding of incoming information has been efficient. It is greatly enhanced if the information to be coded is also presented in rich, complex, contextual frameworks. In other words, the incoming information must be related to the background information already existing in the AL's LTM. Johnstone (1997) likens the storage and recall to a filing system in which new information is related to existing files and placed there. If the incoming information does not fit the system, a

5.5.6 Long Term Memory (LTM)

Once the information passes from WM into the LTM, some permanent storing begins through the encoding process (discussed below). Eggen and Kauchak (1994) claim that the LTM has unlimited storage place where the information from the WM is stored as declarative knowledge (the knowledge of facts, definitions, generalizations, and rules) and procedural knowledge (the knowledge of how to perform activities). Sets of interconnected items of declarative knowledge form propositional networks, which in turn form subsets of schemata. The overall schemata contain networks of both declarative and procedural knowledge. As a result, there are no individual items of information in the LTM, but rather a series of interconnected relationships with others.

5.5.6.1 The cognitive processes of encoding and retrieving

According to Eggen and Kauchak (1994), encoding is the most critical cognitive process in the information-processing model. It is the process whereby the AL forms mental representations of a learning task. Encoding takes place when the information about the incoming stimuli is transferred from the AL's WM to his/her LTM by connecting information that already exists in the AL's LTM. The networks and schemata found in LTM form his/her background knowledge. Organized background knowledge in his/her LTM allows him/her to make connections to new information he/she is learning, and that is coming in from the WM. In this case, the connection becomes the critical feature. Eggen and Kauchak argue further that the attaching of new information to the old is a critical element of the learning process. Learning occurs when the new information is attached to information that already exists in the LTM. They contend further that, "The richer and complex the networks and they are brought about in the structure that is made of those elements. He argues:

> If my thoughts are to be about anything, then the strings must have a meaning, which makes the thoughts about those things. In a word, the mind has more than syntax it has semantics. The reason that no computer programme can ever be a mind is simply that a computer programme is only syntactical, and minds are more than syntical. Minds are semantic, in the sense that they are more than a formal structure, they have a content. (Searle, 1984:31)

Searle (1984) further elaborates his notion about the mind which makes it so distinctly different from an information processing machine in terms of four features of the mind: namely, (1) consciousness, i.e., an awareness of one's action at a given time; (2) intentionality – the feature by which our mental states are directed at, or about, or refer to other than ourselves; (3) subjectivity – e.g. the facts of sensations felt by one and not the other, one's point of view as distinct from those of other people, etc. and (4) the issue of mental causation – i.e. how our thoughts can evoke physical effects like thinking and then raising one's hand, etc.

The renowned psychiatrist Thomas Szasz has also warned about equating the human mind with either a digital computer or even equating or locating the mind in the brain as depicted by philosophers, psychologists and neural scientists. To Szasz (1996):

> Mind is dependent on language, as respiration is dependent on the lung. However, mind is neither brain, nor self, nor language, but the person's ability to have a conversation with himself – the self acting as both speaker and listener – the "I" and the "me" speaking and listening to one another. (p. 2)

Certainly a detailed discussion of this subject is beyond the scope of this study. However, it points out the complexity of mind-body controversy.

processed information is then passed on to the African learner's Long Term Memory (LTM).

According to Eggen and Kauchak (1994), the teacher can once more help the AL by: (1) keeping verbal descriptions short enough and slow enough to prevent the AL' working memory from becoming overloaded; and (2) identifying and highlighting key points in the presentation by writing them on the board, on an overhead projector, or in a handout. A classroom discussion with peers and/or group work activities may bring in the social as well as the symbolic elements depicted in Wortham's (2001) eco-social systems. This instructional strategy is also appropriate for *contiguity learning*. When the teacher provides a brief review of past learning, asks thought-provoking questions, introduces a lesson through brainstorming or summarizes the outcomes of such activities, he/she is appealing to the underlying schemata and constituent elements stored in the learner's LTM. The elements talked about in the Contiguity Learning Hypothesis are ideas, meanings or web of ideas that provide the needed context for articulating the thought systems (Ogunniyi, 2002b). This instructional approach tends to trigger off the whole mechanism of contiguity learning, which in turn may result in *border crossing* and *collateral learning* elucidated earlier depending of course on the success of instruction and consequent internalisation by the learner of what has been taught (see Ogunniyi, 2000). However, Ogunniyi (2002b) has argued that information processing depicted in the foregoing discussion, is only an aspect of a more complex mechanism. He agrees with Searle (1984) that our minds are more complex than a digital computer or a computer programme depicted artificial intelligence. According to Searle (1984) mental processes are caused by the behaviour of elements in the brain. At the same time,

PERFORMANCE PER QUESTION FOR GROUP C_2

Question	C_2				
	Mean %	Mean	S.D	Zero%	Max%
Q1.1	69	0.69	0.44	25	65
Q1.2	90	0.90	0.30	10	90
Q2.1	77	0.77	0.43	16	77
Q3.1	73	0.73	0.44	29	68
Q3.2	77	0.77	0.43	16	77
Q3.3	27	0.44	0.50	55	42
Q3.4	66	1.31	0.76	16	48
Q3.5	20	0.40	0.47	16	35
Q3.6	24	0.68	0.87	58	25
Q3.7	57	1.13	0.48	6	16
Q4.1	52	1.03	1.02	48	52
Q4.2	39	0.77	0.96	58	35
Q4.3	8	0.15	0.50	90	6
Q4.4	29	0.58	0.72	55	13
Q5.1	51	2.05	1.07	13	0
Q5.2	43	0.85	0.86	45	25
Q6.1	44	0.44	0.50	55	42
Q6.2	49	0.97	0.98	48	45
Q7.1	82	0.82	0.38	16	81
Q7.2	51	1.02	0.46	10	6
Q7.3	28	0.56	0.28	10	0
Q7.4	82	0.82	0.38	16	81
Q8	54	1.08	0.76	25	25
Q9.1	47	0.47	0.41	35	29
Q9.2	50	0.50	0.43	35	35
Q9.3	18	0.35	0.39	48	0
Q9.4	65	1.29	0.78	19	48
Q9.5	12	0.23	0.62	87	10
Q10.1	78	2.35	1.05	10	68
Q10.2	70	1.40	0.76	16	55
Q11	55	0.55	0.49	42	52

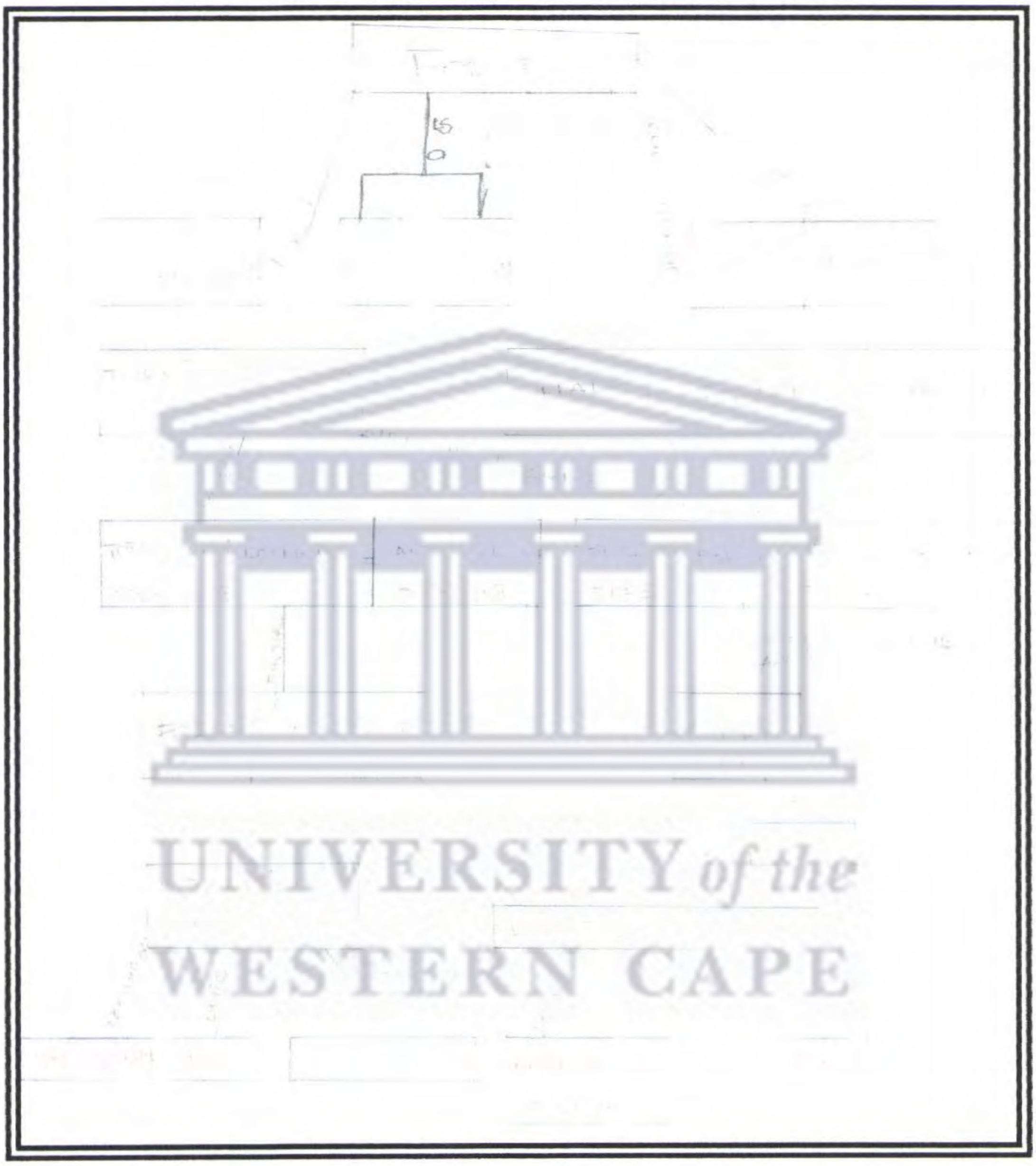
PERFORMANCE PER QUESTION FOR GROUP C_1

Question	C_1				
	Mean %	Mean	S.D	Zero %	Max %
Q1.1	69	0.69	0.47	31	69
Q1.2	49	0.49	0.51	51	49
Q2.1	84	0.84	0.37	16	84
Q3.1	38	0.38	0.49	62	38
Q3.2	76	0.76	0.43	62*	38
Q3.3	27	0.27	0.45	73*	27
Q3.4	47	0.93	0.69	27	20
Q3.5	9	0.18	0.37	80	55
Q3.6	41	0.82	0.93	51	36
Q3.7	37	0.73	0.78	50	18
Q4.1	22	0.44	0.81	76	20
Q4.2	27	0.54	0.58	49	4
Q4.3	4	0.07	0.33	96	2
Q4.4	24	0.48	0.69	62	11
Q5.1	13	0.50	0.93	73	0
Q5.2	50	1.00	0.85	36	33
Q6.1	24	0.24	0.43	76	24
Q6.2	22	0.43	0.78	73	18
Q7.1	67	0.67	0.48	33	67
Q7.2	55	1.10	0.42	4	7
Q7.3	29	0.58	0.28	9	0
Q7.4	80	0.80	0.40	20	80
Q8	2	0.04	0.21	96	0
Q9.1	49	0.49	0.31	20	18
Q9.2	49	0.49	0.31	20	18
Q9.3	9	0.17	0.37	82*	0
Q9.4	41	0.81	0.75	38	20
Q9.5	0	0.00	0.00	100	0
Q10.1	61	1.84	1.19	16	47
Q10.2	40	0.80	0.69	36	16
Q11	43	0.43	0.48	53	40

APPENDIX 8

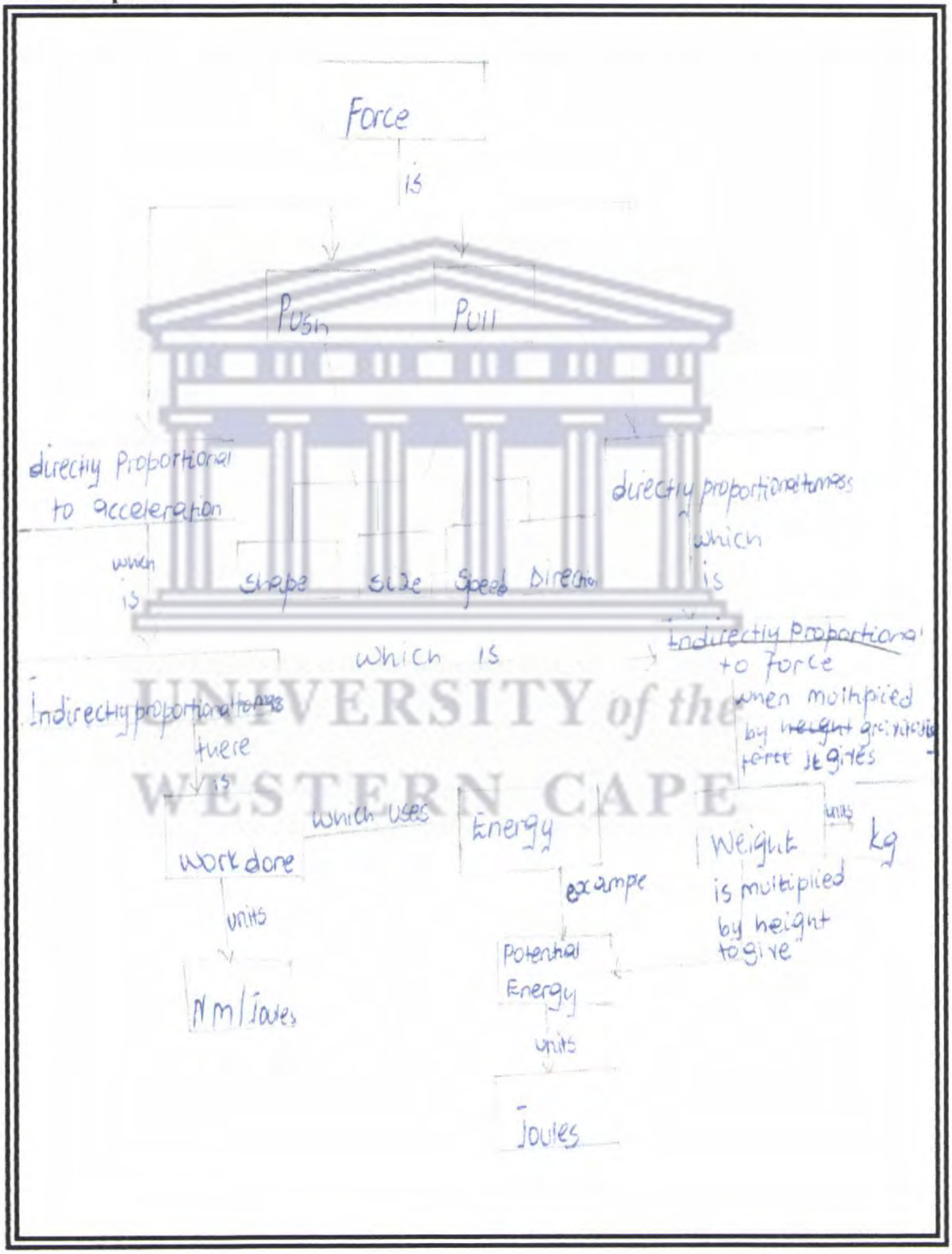
PERFORMANCE PER QUESTION FOR GROUP E

Question	E				
	Mean %	Mean	S.D	Zero%	Max%
Q1.1	54	0.54	0.48	42	50
Q1.2	92	0.92	0.28	8	92
Q2.1	88	0.88	0.33	13	88
Q3.1	47	0.47	0.50	52	46
Q3.2	74	0.74	0.44	25	73
Q3.3	41	0.41	0.49	58	19
Q3.4	52	1.03	0.63	17	21
Q3.5	7	0.13	0.33	88	13
Q3.6	13	0.25	0.58	81	6
Q3.7	39	0.78	0.73	42	16
Q4.1	35	0.70	0.92	60	17
Q4.2	16	0.32	0.62	75	8
Q4.3	10	0.20	0.53	85	6
Q4.4	24	0.47	0.56	56	2
Q5.1	13	0.50	0.95	75	0
Q5.2	40	0.79	0.92	54	31
Q6.1	31	0.31	0.47	69	31
Q6.2	39	0.77	0.92	54	33
Q7.1	81	0.81	0.39	19	81
Q7.2	57	1.13	0.52	8	6
Q7.3	35	0.69	0.32	8	0
Q7.4	90	0.90	0.29	8	88
Q8	48	0.95	0.81	35	25
Q9.1	52	0.52	0.39	27	31
Q9.2	55	0.55	0.43	31	42
Q9.3	24	0.48	0.49	46	4
Q9.4	46	0.92	0.91	44	38
Q9.5	7	0.13	0.53	94	4
Q10.1	52	1.55	1.27	29	38
Q10.2	38	0.65	0.64	44	8
Q11	45	0.45	0.46	48	35



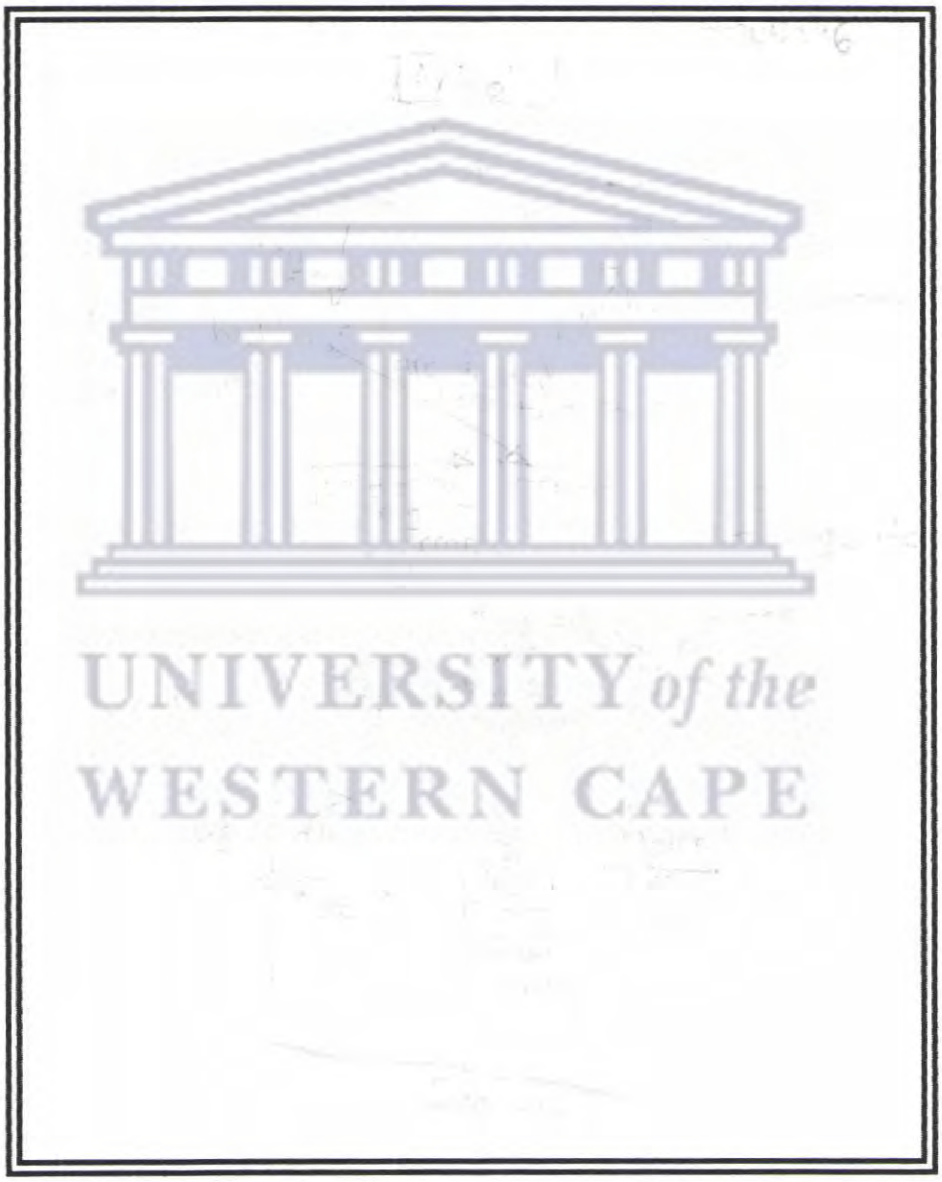
APPENDIX 7

Examples of Concept Maps drawn by the subjects on the topic of force, energy, work and power



APPENDIX 6

Examples of Concept Maps drawn by the subjects on topics of their choice



STORY TWO

Mr. Ngwenya he drinks a lot especially during the maganu season he would drink until he forgets his name. Mr.Ngwenya is also working for Shiselweni forestry and he uses a chain saw, which needs oil that must always be replenished to work properly. One day he went to a shebeen to drink and he met Mr.Vilakati who was known to be a feared witchdoctor of the area, they drank together but latter a fight started between the two, after which Mr.Vilakati sustained injuries and he swore that he was going to bewitch Mr.Ngwenya for what he has done to him. Mr.Ngwenya who was obviously worried about the threats, went to sleep, the following morning he went to work but he had forgotten to replenish the oil for his chain saw. His Foreman gave him notice that due to his poor performance he would be fired if he doesn't improve. Mr.Ngwenya's became worse as he got more worried; he decided to consult a certain witchdoctor, Mr.Dlamini about his situation at work. Mr.Dlamini, the witchdoctor told Mr.Ngwenya that the chain saw was not working properly because of Mr.Vilakati's curse; he had bewitched the machine that's why it cannot cut the wood faster.

QUESTION: Do you agree that the chain saw was affected by Mr.Vilakati's curse or what do you think affected the chain saw?

APPENDIX 5

FICTITIOUS STORIES FOR VIDEOTAPED GROUP DISCUSSION

STORY ONE

Zandile Dlamini grew up in the Dlamini homestead where her father had given instructions to her and the other children that they must never ever bring water to the homestead after sunset. The reason for the instructions was that if you bring water from the river after sunset evil spirits will attack the home, as botokoloshe will be contained in the water. Zandile did obey her father, but one particular day Zandile played for her netball team at school and she came home very late, when the sun was about to set. She took the wheelbarrow and went to the river to fetch water. When she got there she filled up the container with water and put it on the wheelbarrow. Now in order to get home faster she decided to hold the wheelbarrow in a particular way. She started to push it up the slope, but in the process, she sweated a lot, loss a lot of water as the water began to spill and she took longer than usual. When she was about to enter her home her foot got into a hole she tripped, fell and broke her ankle. Zandile, then picked up the wheelbarrow that had fallen also and drove it into the homestead, but her grand mother had watched all what had just happened with her. Zandile's grand mother called her to her hut and said to her " what has happened to you is because you have broken your father's instructions you have brought water into homestead after sunset, the water that contains botokoloshe(evil spirits)," and she ordered Zandile to throw away all the water.

QUESTIONS: Do you agree with Zandile's grand mother that Zandile hurt her ankle because of the evil spirits that came in with the water and that the water that was brought home after sunset was containing evil spirits (botokoloshe)? If you don't agree with Zandile's grandmother what is your opinion about what happened to Zandile? What do you think made her very tired? What made her sweat a lot? Why did she take a very long time to bring the water home? What made her hurt her ankle?

11 Zodwa and Thandi are running in the rain towards home from school on a windy day. Zodwa, who is carrying an umbrella, is running at a slower pace than Thandi who is not carrying one. What do you think is preventing Zodwa from catching up with Thandi?

9.1 A

9.2 B

9.3 C

9.4 How much energy has la-Simelane's hoe gained at the highest point, A?

9.5 At what the speed does the hoe hit the ground each time la-Simelane brings it down?

9.6 La-Simelane did not work in her field the previous day because there was a funeral in the area, even though she did not attend. Why didn't La-Simelane hoe her maize field?

9.6 What could have happened if La-Simelane went ahead and worked in her field?

10. Every Saturday, Jabulane and Vusi use their father's span of oxen to pull a load of firewood from a forest that is 1 km from their homestead.

10.1 If a load of firewood weighs 500N, what will be the amount of work done by the oxen in pulling it?

10.2 If the oxen take 30 minutes to pull the firewood from the forest to the boys' homestead, how much power do they use?

7. Gogo Shongwe is sitting in front of a coal fire in a candle-lit kitchen. Duduzile her granddaughter is busy sweeping the floor. Write down the type(s) of energy and/or energy conversion taking place in

7.1 Gogo Shongwe as she is sitting.

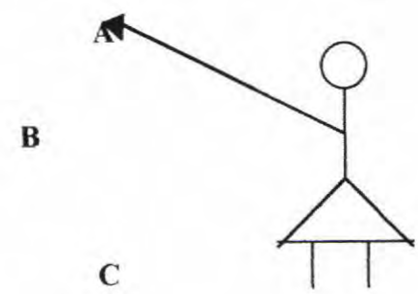
7.2 The coal fire in front of Gogo Shongwe

7.3 The candle that is lighting the room

7.4 Duduzile's broom as she sweeps the floor.

8. Babe Dlamini works for Shiselweni Forestry. His job is to cut down trees using an electric saw (ihhomulayini). One day his foreman (indvuna) was heard complaining that Babe Dlamini was slow. Babe Dlamini defended himself by explaining to the foreman that his saw was no longer a 100% efficient. Explain what Babe Dlamini meant by this.

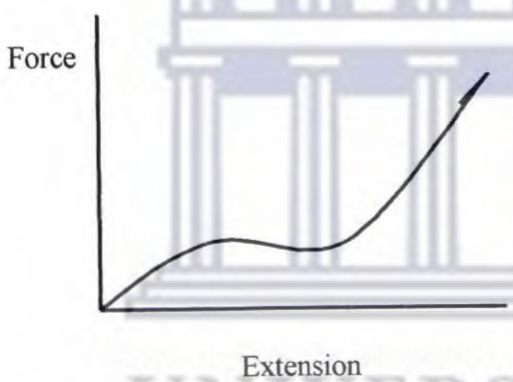
9. Whenever la-Simelane hoes (kuhlakula) her maize fields, she prefers using a 20N hoe which she can raise 2m above the ground. Describe, in terms of kinetic and potential energy, the energy undergone by the hoe at the point:



5. Mandla and his friends like killing birds using catapults (tilingi). One day they brought their catapults to school and their science teacher asked them to design an experiment to show how the catapults stretch whenever they pull them with different forces.

5.1 Outline the steps Mandla and his friends followed in doing the experiment.

5.2 When Mandla plotted the results of his experiment, he got the graph shown below



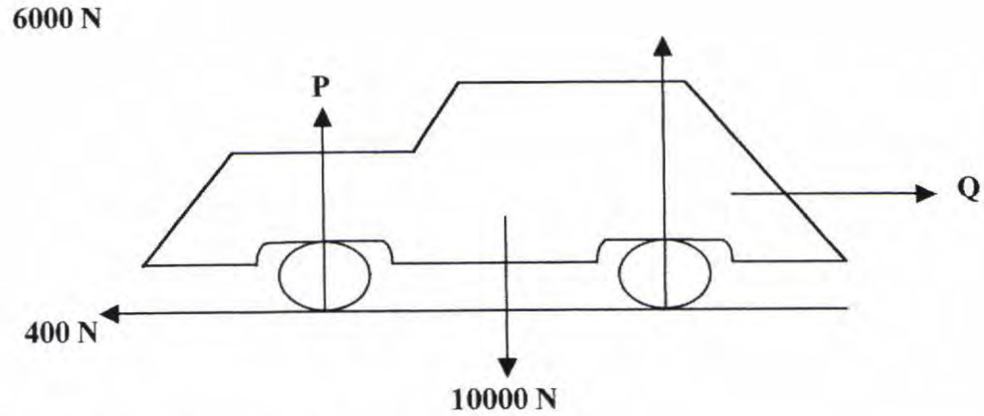
Did Mandla's catapult obey Hooke's Law over the range of values shown? Justify your answer.

---

6. Mr. Zwane is a hefty man weighing 200N. He can easily push heavy objects. However, when he tried to push a 10 kg block on a rough concrete pavement, it only accelerated at 5 m/s.^{2}

6.1 What do you think caused this problem?

6.2 If everything had been normal, what would have been the block's acceleration?



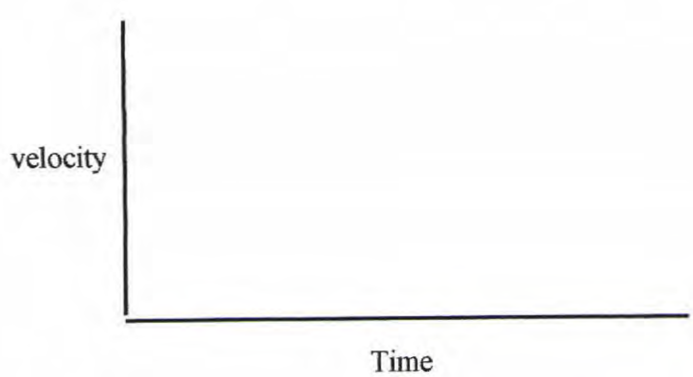
4.1 Calculate the mass of the car.

Mr. Mtsetfwa suddenly looks at his watch and realizes that he will not find the bank open if he drives at this speed. He then presses down the accelerator to make the car move faster. In doing so, Mr. Mtseftwa doubles the 400N driving force.

4.2 Calculate the resultant force driving the car forward at this interval.

4.3 What was the acceleration applied by Mr. Mtsetfwa on the car?

4.4 In the axes below, draw a sketch graph showing how the velocity of the car changes with time (start your graph just before the driving force is doubled.)



3.2 On the diagram label the position of the pivot (fulcrum), P.

3.3 On the diagram draw an arrow to show the force that the screwdriver exerts on the lid.

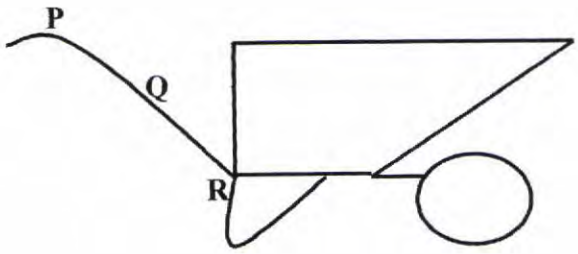
3.4 Calculate the moment of the 20N force applied by Sipho about the pivot.

3.5 State the principle applied by Sipho in opening the tin.

3.6 Use this principle to calculate the force F exerted by the screwdriver on the lid.

3.7 If the force F was too small to lift the lid, suggest two things Sipho could have done to increase it.

4. Mr. Mtsetfwa is driving his front wheel drive car from Mbukwane to Nhlangano. The car is traveling at constant velocity. The forces acting on the car are shown on the diagram. Q is the force of air on the moving car and P is the total upward force on the front wheels. Q = 400N and P= 4000N



P □ Q □ R □

2.2 Siphiwe has to also make sure that she brings the water into her homestead before sunset. What could be the reason for this?

____

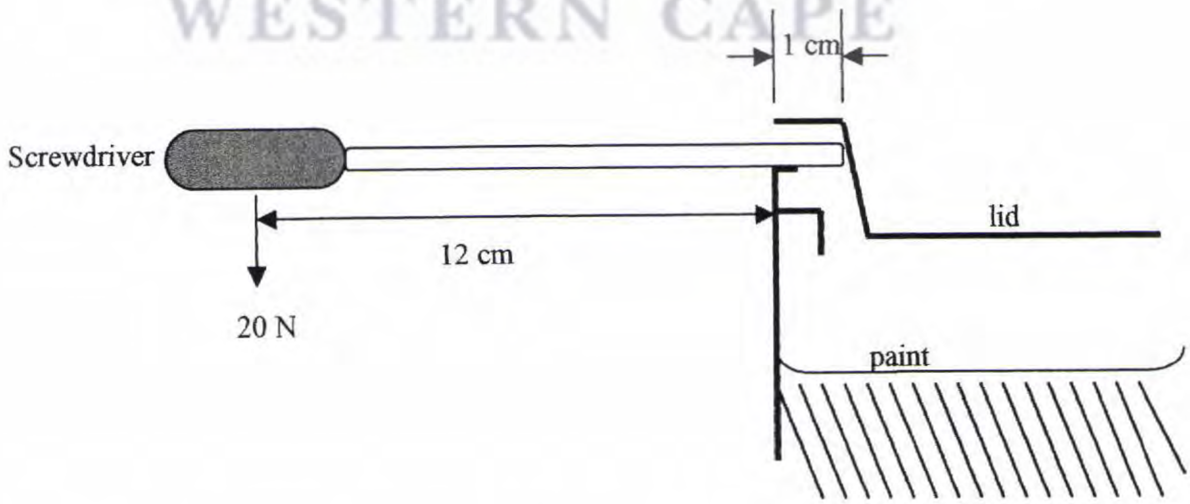
____

2.3 What would happen if Siphiwe disobeyed this?

____

____

3. Sipho wanted to open a paint tin using his hands, but could not. He looked around the tool shed and found a screwdriver, which he then pushed 1 cm under the lid and applied a force of 20N and the tin opened.



3.1 Why was Sipho not able to open the paint tin with his hands?

APPENDIX 4

PHYSICS ACHIEVEMENT TEST

Please answer **All** the questions below.

PART A

Your initials: ______________

Gender: Male ☐ Female ☐

Age: Below 16 years ☐
16 years old ☐
17 years old ☐
18 years old ☐
Above 18 years old ☐

Interest in Science: High ☐ Low ☐ No interest ☐

PART B

1. Many things around your home demonstrate the moment of a force.

1.1 In your own words, define the "moment of a force".

____

____

1.2 Give an example of a moment of a force found around your home.

____

____

2. Siphiwe always uses a wheelbarrow to fetch water from the river when she returns home from school because she finds it easier to use it than carrying the water on her head. However, she has also realized that even the wheelbarrow can be difficult to push when its handles are held incorrectly.

2.1 At which point P, Q or R did Siphiwe find it easiest to push the wheelbarrow. (Tick the correct letter)

APPENDIX 3

MIAN ANALYSIS ACCORDING TO DEMOGRAPHIC FACTORS

TABLE 1: MIAN ANALYSIS ACCORDING GENDER

Categories	Males (%)			Females (%)		
	A	DA	DK	A	DA	DK
1.Magic and Mysticism	37	39	22	41	34	22
2. Metaphysics, Parapsychology, Pseudoscience	35	43	21	32	44	23
3. Spiritism	33	48	19	33	47	19
4. Rational	33	40	26	36	40	23
5. Science	49	33	17	40	38	24

TABLE 2: MIAN ANALYSIS ACCORDING TO AGE

	<17 yrs (%)			17 yrs (%)			18 yrs (%)			19 yrs (%)			>19yrs (%)		
	A	DA	DK	A	DA	DK	A	DA	DK	A	DA	DK	A	DA	DK
1	44	36	20	33	42	28	38	36	23	43	44	19	23	48	30
2	31	42	27	32	39	27	35	46	20	36	47	16	33	44	22
3	36	42	21	38	42	23	37	42	22	36	44	21	34	44	22
4	39	40	21	33	37	44	22	40	35	27	46	25	19	40	36
5	40	35	26	50	33	16	47	36	16	44	35	20	42	31	28

TABLE 3: MIAN ANALYSIS ACCORDING TO INTEREST IN SCIENCE

Category	High Interest (%)			Low Interest (%)		
	A	DA	DK	A	DA	DK
1.Magic and Mysticism	39	41	22	32	35	28
2. Metaphysics, Parapsychology, Pseudo-science	33	44	19	30	40	29
3. Spiritism	32	50	18	34	46	20
4. Rational	35	41	26	28	46	24
5. Science	47	33	19	33	42	22

TABLE 4: RATIONAL

Item	A (%)	DA (%)	DK (%)
2. The people and animals could not swim out and were eaten by crocodiles	56	33	10
6. A red train was hidden on the B-side of the valley and so was not seen.	32	50	17
13. It is just a coincidence	35	22	42
25. Doctors are too proud to find out about sickness from the tinyangas.	17	54	29
Total	35	40	25

TABLE 5: SCIENCE CATEGORY

Item	A (%)	DA (%)	DK (%)
8. There were two trains each with large magnets, which push away the other train without touching it.	36	42	22
17. The brain does not stop immediately the heart stops, so after life experience is like a dream stored up in the brain before it stops.	28	50	22
31. Animals have more sensitive parts than human beings.	66	19	11
34. Slight changes in wind or earth can be detected by the senses of animals.	44	29	24
Total	44	35	20

TABLE 3: SPIRITISM

Item	A (%)	DA (%)	DK (%)
1. The people and animals are caught up into the other world	5	72	24
3. The seven-headed snake was responsible for their disappearance	49	26	26
5. The people and animals have been taken away by the ancestral spirits	17	58	23
18. A person's spirit does not die with his body, it leaves the body at death	69	19	10
19. People who died and later came back to life have merely visited the other world.	22	55	25
20. The soul of a dead person which is unable to find a body in the other world returns to the owner	7	68	26
21. Traditional medicine (muti) is superior to modern medicine.	24	60	16
22. The tinyangas always know the cause of every disease.	16	77	8
23. Modern doctors cannot detect activities of devils as tinyanga can do.	79	12	8
24. Traditional healers do not deal only with those things, which can be seen, but also what we cannot see.	61	18	19
30. The gods living in the farm or soil cause seeds to germinate faster.	14	70	16
33. Animals have spirits, which warn them about coming dangers.	34	47	23
Total	33	49	19

TABLE 2: METAPHYSICS, PARAPSYCHOLOGY, AND PSEUDOSCIENCE

Item	A (%)	DA (%)	DK (%)
11. Your mind knowing things before you see them	54	41	6
12. Your mind seeing farther than your eyes	67	25	5
14. Your mind acting as a magnet or special type of computer.	44	47	10
16. When a person dies his/her soul lives.	56	31	11
26. Magnets speed up the ability of the seeds to germinate faster.	23	52	25
27. Magnets have put a vita (powerful) force inside the seeds causing them to germinate quickly.	32	45	23
28. The force of the magnets acts like the trigger of a gun which pushes the seeds to germinate quickly.	21	52	21
29. The force of the magnets and some other unknown forces caused the seeds to germinate faster.	19	41	39
32. Animals are closer to nature than we are.	46	38	16
35. Animals were once super human beings with the ability to know things.	9	56	33
36. Have things in their bodies that shine brightly like stars in the sky.	10	60	28
37. Have substances in them that can attract or push away other things.	28	34	35
39. Are not the only beings living in the universe; others live here too.	43	27	25
40. Can shine like the sun, moon and stars when they are in space.	14	57	36
Total	33	43	22

APPENDIX 2

MIAN ANALYSIS ACCORDING TO WORLDVIEW CATEGORIES

TABLE 1: MAGIC AND MYSTICISM

Item	A (%)	DA (%)	DK (%)
4. It is one of those unsolved mysteries	44	20	35
7. The whole event is strange and difficult to explain just like all other strange things	51	33	15
9. The people were under the influence of magic and could not see or think clearly.	32	53	16
10. This is one example of the wonders of science	53	20	25
15. The strange world we live in.	16	62	23
38. Have powerful forces in them that can affect things or people either for good or bad.	34	32	32
Total	38	37	24

STORY SEVEN

Often animals are faster than us in knowing changes around us. For example, animals will start to run away before a strong wind, rain or certain disasters come.

This is because:	A	DA	DK
31 Animals have more sensitive parts than human beings.			
32 Animals are closer to nature than we are.			
33 Animals have spirits, which warn them about coming dangers.			
34 Slight changes in wind or earth can be detected by the senses of animals.			
35 Animals were once super human beings with the ability to know things.			

Suggest your own explanations

STORY EIGHT

Reports of space probes have shown that certain materials in space glow or shine brightly when they approach human beings.

This shows that human beings:	A	DA	DK
36 Have things in their bodies that shine brightly like stars in the sky.			
37 Have substances in them that can attract or push away other things.			
38 Have powerful forces in them that can affect things or people either for good or bad.			
39 Are not the only beings living in the universe; others live here too.			
40 Can shine like the sun, moon and stars when they are in space.			

Suggest your explanation:

other world returns to the owner			

Suggest your own explanation:

STORY FIVE

Some diseases are very difficult to cure by modern doctors and yet are cured quite easily by traditional healers (tinyanga). A Swazi girl suffering from acute hysteria (lihabiya) could not be curd in a hospital was cured within a week by a traditional healer.

This is because:	A	DA	DK
21Traditional medicine (muti) is superior to modern medicine.			
22The tinyangas always know the cause of every disease.			
23Modern doctors cannot detect activities of devils as tinyanga can do.			
24Traditional healers do not deal only with those things, which can be seen, but also what we cannot see.			
25Doctors are too proud to find out about sickness from the tinyangas.			

Suggest your own explanation:

STORY SIX

Peanut seeds kept in a box containing magnets were found to germinate faster than those not kept in the box.

This is because:	A	DA	DK
26Magnets speed up the ability of the seeds to germinate faster.			
27Magnets have put a vita (powerful) force inside the seeds causing them to germinate quickly.			
28The force of the magnets acts like the trigger of a gun which pushes the seeds to germinate quickly.			
29The force of the magnets and some other unknown forces caused the seeds to germinate faster.			
30The gods living in the farm or soil cause seeds to germinate faster.			

Comments:

STORY TWO

A group of people saw a blue train going down the A-side of a deep valley. After a while they saw a red train coming out on the B-side of the same valley. Later the same train reversed back into the same valley and then the blue train came out again on the A-side of the valley.

May be:	A	DA	DK
6A red train was hidden on the B-side of the valley and so was not seen.			
7The whole event is strange and difficult to explain just like all other strange things			
8There were two trains each with large magnets, which push away the other train without touching it.			
9The people were under the influence of magic and could not see or think clearly.			
10This is one example of the wonders of science			

Suggest your own explanation:

STORY THREE

You were thinking about a friend you had not seen fore a long time and suddenly he/she appears!

This is an example of:	A	DA	DK
11Your mind knowing things before you see them			
12Your mind seeing farther than your eyes			
13It is just a coincidence			
14Your mind acting as a magnet or special type of computer.			
15 The strange world we live in.			

Suggest your own explanation:

STORY FOUR
People who fall into a coma or die for a while often come up with interesting stories about their experience in the after life?

This is because:	A	DA	DK
16When a person dies his/her soul lives.			
17The brain does not stop immediately the heart stops, so after life experience is like a dream stored up in the brain before it stops.			
18A person's spirit does not die with his body, it leaves the body at death			
19People who died and later came back to life have merely visited the other world.			
20The soul of a dead person which is unable to find a body in the			

APPENDIX 1

MY IDEA ABOUT NATURE

Please fill the form and answer the questions as honestly as you can. There are no right or wrong answers but do not guess.

PART A

Initials: ________

Sex: Male ☐ Female ☐

Age: Below 16 years ☐
16 years old ☐
17 years old ☐
18 years old ☐
Above 18 years ☐

Interest in science: High ☐ Low ☐ No interest ☐

PART B

Read the stories below and tick (√) to show whether you agree (A), disagree (D) or don=t know (DK) about the following statements. Do not tick more than one response per item.

STORY ONE

The Mantjolo dam belonging to the Mnisi clan has been described as sacred. Many people and animals have disappeared mysteriously without any trace on entering the dam without permission from the clan.

People believe that:	A	DA	DK
1The people and animals are caught up into the other world			
2The people and animals could not swim out and were eaten by crocodiles			
3The seven-headed snake was responsible for their disappearance			
4It is one of those unsolved mysteries			
5The people and animals have been taken away by the ancestral spirits			

Suggest your own explanation:

Zangari, W. and Marchdo, F.R. (2001). Parapsychology in Brazil: A Science Entering Young Adulthood. *The Journal of Psychology*, 65 (4), 351-357.

The Oxford English Dictionary. (1978) Vol. VI L-M. Oxford : Clarendon Press.

The Statesman's Year Book: the Politics, Cultures and Economies of the World 2002. Bath: Palgrave Publishers, Ltd.

The Webster Comprehensive Dictionary. (1995). Chicago: J.G. Ferguson Publishing Company.

Tobin, K. (1996). *Cultural Perspectives on the Teaching and Learning of Science. Report of an International Scientific Research Programme* (Joint Research) Funded by the Grant-in-Aid for Scientific Research, Ibaraki, Japan, pp 31-47.

Tuckman, B.W. (1978). *Conducting Educational Research.* New York: Harcourt Brace Jovanovich, Inc.

Urevbu, A.D. (1984). Teaching Concepts of English to Nigerian Children in the 7 – 11 years old range. *Journal of Research in Science Teaching*, 12(3), 255 – 267.

Vygotsky, L.S. (1986). *Thought and Language* (A.Kozulin, trans.). Cambridge: MA: MIT.

Waldrip, B.G. and Taylor, P.C. (1999). Permeability of Students' Worldview to their School Views in a Non-Western Developing Country. *Journal of Research in Science Teaching*, 36(3), 289-303.

Wheatley, G.H. (1991). Constructivist Perspectives on Science and Mathematics Learning. *Science Education*, 75(1), 9-21.

Woolfolk, A.E. and McCune Nicolich, L. (1980). *Educational Psychology for Teachers.* Englewoods Cliff: Prentice Hall.

Wortham, S. (2001). Interactionaly Situated Cognition: A Classroom Example. *Cognitive Science*. 25(1), 37- 58.

Solomon, J. (1985). The Pupils' View of Electricity. *European Journal of Science Education*, 7(3): 281-294

Solomon, J. (1987). Social Influence on the Construction of Pupils' Understanding of Science. *Studies in Science Education*, 14, 63-82.

Solomon, Z. (2001). *An analysis of Eritrean Grade 10 students' understanding of simple electric circuits.* An unpublished Masters' Thesis

Sutherland, D. and Dennick, R. (2002). Exploring Culture, Language and the Perception of the Nature of Science. *International Journal of Science Education*, 24(1), 1-25.

Swift, D. (1992). Indigenous Knowledge in the Service of Science and Technology in Developing Countries. *Studies in Science Education*, 20, 1-28.

Szasz, T. (1996). *The Meaning of Mind: Language, Morality and Neural Science*. Wesport: Prager.

Taylor, P.C. (1997). Constructivism: Value Added. Iin B. Frash and K. Tobin (eds). *The International Handbook of Science Curriculum.* Dordretch, the Netherlands: Kluwer Academmic Press, 1-22

Tesfai, G. (2001). *Grade 10 Eritrean Students' Conceptions of the Human Circulatory System*. An unpublished Master's Thesis.

Thijs, G.D. (1992). Evaluation of an Introductory Course on Force Considering Students' Pre-conceptions. *Science Education*, 76(2), 155 – 174.

Thijs, G.D. and Van Den Berg, E. (1995). Cultural Factors in the Original and Remediation of Alternative Conceptions in Physics. *Science Education*, 4, 317-347

The Europa World Year Book 2001. London: Europa Publications.

The Concise Oxford Dictionary (1990).

Proper, H.; Wideen, M.F. and Ivany, G. (1988). Worldview Projected by Science Teachers: a Study of Classroom Dialogue. *Science Education*, 72(5), 547-560

Regional Surveys of the World: Africa South of the Sahara 1997. London: Europa Publications, Ltd.

Rollnick, M.S. (1998). The Influence of Language on the Second Language Teaching and Learning of Science. In W.W. Cobern (ed.) *Socio-Cultural Perspectives on Science Education: An International Dialogue*. Dodretch: Kluwer Academic Publishers.

Rollnick, M.S. (2000). Current Issues and Perspectives on Second Language Learning of Science. *Studies in Science Education*, 35, 93-122.

Rollnick, M.S and Rutherford, M. (1996). The use of Mother Tongue and English in the Learning and Expression of Science Concepts: A Classroom Based study. *International Journal of Science Education*, 18(1): 91-104.

Runes, D. (ed.) (1975). *Dictionary of Philosophy*. Tutowa, N.J.: Littlefield, Adams & Co., p.203

Schumacher, S. and McMillan, J.H. (1993). *Research in Education: A Conceptual Introduction*. New York: Harper Collins College Publishers.

Searle, J. (1984). *Minds, Brains and Science*. London: Penguin Books.

Smith, E. (1995). Where is the Mind? Knowing and Knowledge in Cobb's Constructivist and Sociocultural Perspectives. *Educational Researcher*, 24(6), 23-24.

Snively, G. and Corsiglia, J. (2001). Discovering Indigenous Science: Implications for Science Education. *Science Education*, 85(1), 6-34

Ogunniyi, M.B. and Yandila, C.D. (1994). Alternative Conceptions of Natural Phenomena Held by Botswana and Nigerian Secondary School Science Teachers. *Southern African Journal of Mathematics and Science Education*, 1(1), 77 – 86.

Okebukola, P.A. (1986). The Influence of Preferred Learning Styles on Co-operative Learning in Science. *Science Education*, 70(5), 509 – 517.

Okebukola, P.A. and Jegede, O.J (1988). Cognitive Preference and Learning Mode as Determinants of Meaningful Learning through Concept Mapping. *Science Education*, 72(4), 489-500.

Okebukola, P.A. and Jegede, O.J. (1990). Eco-Cultural Influence upon Students' Concept Attainment in Science. *Journal of Research in Science Teaching*, 27(7), 661-669.

O'loughlin, M. (1992). Rethinking Science Education: Beyond Piagetian Constructivism Towards a Socio-cultural Model of Teaching. *Journal of Research in Science Teaching*. 29(8), 791-820

Osborne, J.F. (1996). Beyond Constructivism. *Science Education*, 80(1), 53 – 82.

Phelan, P.; Davidson, A. and Cao, H. (1991). Students' Multiple Worlds: Negotiating the Boundaries of Family, Peer and School Cultures. *Anthropolgy and Educational Quartely*, 22(3), 224-250.

Phillips, D.C. (1995). The Good, the Bad, and the Ugly: The Many Faces of Constructivism. *Educational Researcher*, 24(7), 5-12.

Piaget, J. (1926). *The Language and Thought of the Child.* New York: Harcourt, Bruce and Company.

Ogunniyi, M.B. (1997). Multiculturalism and Science Education Research in the New South Africa. *Proceedings of the 5th Annual Meeting of the Southern African Association for Research in Mathematics and Science Education.*

Ogunniyi, M.B. (ed.) (1998). Promoting Public Understanding of Science and Technology in Southern Africa. *Proceedings of a Southern African Conference*. Cape Town: SSME, UWC: 38-53.

Ogunniyi, M. B. (1999). *Assessment of Grade 7 – 9 Pupils' Knowledge and Interest in Science and Technology*. University of the Western Cape: SSME.

Ogunniyi, M.B. (2000). Teachers' and Pupils' Scientific and Indigenous Knowledge of Natural Phenomenon. *Journal of Southern African Association of Research in Mathematics, Science and Technology Education*, 4(1), 70 – 77.

Ogunniyi, M.B (2002a). Border Crossing Between Distinct World Views. *Proceedings of the 10th Annual Meeting of the Southern African Association for Research in Mathematics , Science and Technology Education,*University of Natal, Durban, 68 - 75.

Ogunniyi, M.B. (2002b). *Border Crossing into School Science and the Contiguity Learning Hypothesis.* Paper presented at the NAST Conference.

Ogunniyi, M.B. and Fakudze, C.G. (2002). *Conceptions Of Electricity Among Grade Eight South African Students*. A working paper

Ogunniyi, M.B.; Jegede, O.J.; Ogawa, M.; Yandila, C.D.; and Oladela, F.K. (1995). Nature of World View Suppositions Among Science Teachers in Botswana, Indonesia, Japan, Nigeria and the Phillipines. *Journal of Research in Science Teaching*, 32 (8), 817-831.

Novak, J.D. and Gowin, D.B. (1984). *Learning How To Learn.* Cambridge: Cambridge University Press.

Ogawa, M. (1986). Towards a New Rational of Science Education in a Non-Western Society. *European Journal of Science Education*, 8,113-119

Ogawa, M. (1989). Beyond the Tacit Framework of 'Science' and 'Science Education' among Science Educators. *International Journal of Science Education*, 10(1), 1-9.

Ogawa, M. (1995). Science Education in a Multi-science Perspective. *Science Education*, 79(5), 583-593.

Ogunniyi, M.B. (1986). *Teaching Science in Africa.* Ibadan: Salem Media (Nig.) Ltd.

Ogunniyi, M.B. (1987). Conceptions of Traditional Cosmological Ideas Among Literate and Nonliterate Nigerians. *Journal of Research in Science Teaching*, 24(2), 107-117

Ogunniyi, M. B. (1988). Adapting Western Science to Traditional African Culture. *International Journal of Science Education*, 10 (1), 1-9

Ogunniyi, M.B. (1992). *Understanding Research in Social Sciences.* Ibadan: University Press.

Ogunniyi, M.B. (1995). World View Hypothesis and Research in Science Education. *Proceedings of the Annual Meeting of the Southern African Association for Research in Mathematics and Science Education*, 613-624.

Ogunniyi, M.B. (1996). *Science Education in a Multi-cultural South Africa.* A Report of an International Scientific Research Programme funded by the Grant-in-Aid for Scientific Research, Ibaraki, Japan.

Matthews, C.E. and Smith, W.S. (1994). Native American Related Materials in Elementary Science Instruction. *Journal of Research in Science Teaching*, 31(4), 363-380

Marshall, S. (1999). Swaziland. http://www.members.tripod.com/stewart marshall/swaziland.htm

Marwick, B.A. (1966). *The Swazi*. London: Frank Cass and Company, LTD.

McKinley, E.; McPherson-Waiti, P. and Bell, B. (1992). Language, Culture and Science Education. *International Journal of Science Education*, 14(5), 579-595.

Moates, D.R. and Schumacher, G.M. (1980). *An Introduction to Cognitive Psychology*. Belmount: Wadsworth Publishing Company.

Moore, B.J. (1998). Situated Cognition versus Traditional Cognitive Theories Of Learning. *Education*, 161-171

Morris, W. (ed.) (1982). *The American Heritage Dictionary of the English Language*. Boston: Houghton Mifflin Company.

Mousley, J.A. and Clements, M.A. (1990). The Culture of Mathematics Classrooms. In K. Clements (ed.), *Whither Mathematics?* Melbourne: Mathematical Association of Victoria, 398 – 406.

Ninnes, P.M. (2000). Representations of Indigenous Knowledges in Secondary School Science Textbooks in Australia and Canada. *International Journal of Science Education*, 22(6), 603-617.

Novak, J.D. (1988). Learning Science and the Science of Learning. *Science Education*, 15, 77-101.

Novak, J.D. (1990). Concept Mapping: A useful Tool for Science Education. *Journal of Research in Science Teaching*, 27(10), 937-49

Lee, O.; Fradd, S.H. and Sutman, F.X. (1995). Science Knowlegde and Cognitive Strategy Use Among Culturally and Linguistically Diverse Students. *Journal of Research in Science Teaching*, 32(8), 799 – 816.

Lemarchand, R. (1977). *African Kingships in Perspective*. London: Frank Cass and Company LTD.

Lemke, J.L. (1990). *Talking Science: Language, Learning and Values*. Norward, NJ: Ablex

Locust, C. (1988). Wounding the Spirit: Descrimination and Traditional American Indian Belief System. Havard Educational Review, 58(3), 315-330

Lowe, J.A. (1995). The impact of School Science on the World View of Solomon Islands Students. *Prospects*, 25 (4), 653-667.

Lubben, L.; Netshisaulu, T. and Campbell, B. (1999). Students' Use of Cultural Metaphors and Their Scientific Understanding Related to Heating. *Science Education*, 83(6), 761- 774

Lynch, P. (1996a). Students' Alternative Frameworks for the Nature of Matter: A Cross-cultural Study of Linguistic and Cultural Interpretations. *International Journal of Science Education*, 18(6), 743-752.

Lynch, P. (1996b). Students' Alternative Frtameworks: Linguistic and Cultural Interpretations Based on a Study of a Western Tribal Continuum. *International Journal of Science Education*. 18(3), 321-332

Manzini, S. (2000). Learners' Attitudes towards the Teaching of Indigenous African Science as part of the School Science Curriculum. *Journal of the Southern African Association for Research in Mathematics, Science and Technology Education*, 4(1), 19-32.

Klausmeier, H.J. (1980). *Learning and Teaching Concepts: A Strategy for Testing Applications of Theory.* New York: Academic Press.

Knain, E. (1999). Sense and Sensibility in Science Education: Developing Rational Beliefs Through Cultural Approaches. *Studies in Science Education*, 33, 1-29.

Kulkarni, V.G. (1988). The Effect of Language in Science Education. In P. Fensham (ed), *Development and Dilemmas in Science Education.* London: the Falmer Press.

Kuper, H. (1980). *An African Aristocracy: Rank Among the Swazis.* New York: Africana Publishing Company.

Kuper, H. (1986). *The Swazi: A South African Kingdom.* New York: Holt, Rinehart and Winston.

Kyle, W.C. (2002). The Integration of Knowledge Systems: Subjectivity, Awareness, Critique and Agency. *A presentation at the School of Science and Mathematics Education, University of the Western Cape, Cape Town.*

Lawrenz, F. and Gray, B (1995). Investigation of Worldview Theory in a South African Context. *Journal of Research in Science Teaching*, 32(6), 555-568.

Leach, J. and Scott, P. (2000). Children's Thinking, Learning, Teaching and Constructivism. In M. Monk and J. Osborne (eds.) *Good Practice in Science Teaching: What Research has to say.* Buckingham: Open University Press.

Lee, O. (1997). Diversity and Equity for Asia American Students in Science Education *Science Education,*81(1), 107-122

Jegede, O.J. and Okebukola, P.A. (1989). Some Socio-cultural Factors Militating Against Drift Towards Science and Technology in Secondary Schools. *Research in Science and technological Education*, 7, 141 - 151

Jegede, O.J. and Okebukola, P.A. (1991a). The relationship Between African Traditional Cosmology and Students' Acquisition of a Science Process Skill. *International Journal of Research in Science Education*, 13(1), 37-47.

Jegede, O.J. and Okebukola, P.A. (1991b). The Effect of Instruction on Socio-cultural Beliefs Hindering the Learning of Science. *Journal of Research in Science Teaching*, 28, 227-285.

Jenkins, E.W. (2000). Constructivism in School Science Education: Powerful Model or the Most Dangerous Intellectual Tendency? In R. Millar, J. Leach and J. Osborne (eds). *Improving Science Education: The Contribution of Research.* Buckingham: Open University Press.

Jobe, G. (1962). *Dictionary of Mythology, Folklore and Symbols.* New York: The Scarecrow Press.

Johnstone, A.H. (1997). Chemistry Teaching – Science or Alchemy? *Journal of Chemical Education*, 74(3), 262-268.

Kawagley, A.O.; Norris-Tull, D. and Norris-Tull, R.A. (1998). The Indigenous World View of Yupiaq Culture: Its Scientific Nature and Relevance to the Practice and Teaching of Science. *Journal of Research in Science Teaching*. 35(2), 133-144

Kinchin, I.M. (2001). If Concept Mapping is so Helpful to Learning Biology, Why aren't we all Doing it? *International Journal of Science Education*, 23(12), 1257 – 1269.

Heuvelen, A.V. (1982). *Physics: A General Introduction.* Boston: Little, Brown and Company.

Hewson, M.G. and Hamlyn, J. (1984). The Influence of Intellectual Environment on Conceptions of Heat. *European Journal of Science Education*, 6, 245 – 262.

Iwu, M. (1995). Contributions of Traditional Medicine to Health. In S.H. Davis, and K., Ebbe (eds). *Traditional Knowledge and Sustainable Development.* Proceedings of a Conference held at The World Bank, Washington, D.C., 7 – 42.

Jegede, O.J. (1995). Collateral Learning and the Eco-Cultural Paradigm in Science and Mathematics Education in Africa. *Studies in Science Education*, 25, 97-137.

Jegede, O.J. (1996). *Fostering Students" Understanding of Science Concepts.* A Special Keynote Paper for the 37th Annual Conference of the Science Teachers' Association of Nigeria, Uyo, Akwam Ibom State.

Jegede, O.J. (1997a). School Science and Development of Scientific Culture: a Review of Contemporary Science Education in Africa. *International Journal of Science Education* 19(1), 1-20

Jegede, (1997b). *Traditional Cosmology and Collateral Learning in Non-Western Science* Classrooms in Report of an International Scientific Research Programme (Joint Research) Funded by the Grant-in-Aid for Scientific Research, Ibaraki, Japan.

Jegede, O.J. and Aikenhead, G.S. (1999). Transcending Cultural Borders: Implications for science Teaching. *Research in Science and Technological Education*, 17 (1), p45-67.

Goode, E. (2002). Education, Scientific Knowledge, And Belief In The Paranormal. *Skeptical Inquirer*, 26(1), 24-28

Govander, N. (1999). *A Phemenographic Case Study of Physics Students' Experience of Sign Conventions in Mechanics.* An Unpublished Doctoral Thesis. University of Western Cape

Greenfield, T.A. (1996). Gender, Ethnicity, Science Achievement, and Attitudes. *Journal of Research in Science Teaching*, 33(8), 901- 933.

Gunstone, R. and White, R. (2000). Goals, Methods and Achievements of Research in Science Education. In R. Millar, J. Leach and J. Osborne (eds). *Improving Science Education: The Contribution of Research.* Buckingham: Open University Press.

Hacking, M.W. and Garnett, P.J. (1985). Misconceptions of Chemical Equilibrium. *European Journal of Science Education*, 7(2), 205-214

Haidar, A. (1997). Arab Prospective Science Teachers' Worldviews: Presuppositions Towards Nature. *International Journal of Science Education*, 19, 1093-1109.

Haidar, A. (1999). Emirates Pre-service and In-service Teachers' Views About the Nature of Science. *International Journal of Science Education*, 21, 807-822

Haidar, A.H. (2002). Emirates Secondary Schol Science teachers' Perspectives on the Nexus Between Modern Science and Arab Culture. *International Journal of Science education*, 24(6), 611-626.

Heinz-Fry, J.A. and Novak, J.D. (1990). Concept Mapping brings Long-term Movement towards Meaningful Learning. *Science Education*, 74(4), 461-472.