Learning of science concepts within a traditional socio-cultural environment

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The learning of science concepts within a traditional socio-cultural environment were investigated by looking at: 1) the nature of "cognitive border crossing" exhibited by the students from the traditional to the scientific worldview, and 2) whether or not three learning theories/hypotheses: border crossing, collaterality, and contiguity were applicable to their science conceptions. At the end of the instructional intervention, the discussions of two groups, each consisting of ten subjects from the experimental and 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 students exhibited 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 'Cognitive Border Crossing Learning Model' (CBCLM), 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 study raised issues for further research.

Introduction

This article describes how learning of science concepts takes place within a traditional socio-cultural environment. It also proposes a Cognitive Border Crossing Learning Model (CBCLM), developed by the author, as a possible way of describing the process of learning science within a worldview scenario other than that of science. The article is divided into three sections. The first section describes the three constructs that were used by the researcher as a theoretical framework for the CBCLM. These are the Border Crossing theory by Aikenhead (1996), the Collateral Learning theory by Jegede (1995), and the Contiguity Learning theory by Ogunniyi (2002). The second section illustrates how each construct was verified in using data from the researcher's doctoral study (Fakudze, 2002). The third section describes how the researcher combined the three constructs in order to produce the CBCLM. Each component of the CBCLM is described as well as the relationship between the three constructs.

Three theoretical constructs

Numerous recent studies have adopted a cultural view towards science education in that it constitutes science teaching as a cultural activity in the contrived classroom situation (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 whereby a student accommodates school science into his/her cosmology whilst 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. According to this cultural view, to acquire the culture of science, students must intellectually shift from their everyday life-world with its traditional worldview suppositions to that of school science, hence undergoing a process known as cognitive border crossing (Aikenhead & Jegede, 1999). Obviously there are bound to be conflicts.

According to Aikenhead (1996), culture consists of norms, beliefs, values, expectations and conventional actions of a group. 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. Further Thijs and Van Den Berg (1995) have asserted that cultural factors relative to students' alternative conceptions regarding school science include: language, environment, social structure characteristics, traditional values and beliefs, modes of thought and epistemology.

At a personal level, an individual's beliefs, values and so forth can be viewed as his/her worldview. According to Lee and Good (1999), a person's worldview "provides the cognitive lens through which he or she views and interprets phenomena in the world". The concept of 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. 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." A person's worldview can be traditional or scientific. A traditional worldview is a system of thought that is anthropomorphic, monistic and metaphysical in nature (Ogunniyi, 1988; Jegede, 1997). A scientific worldview, on the other hand, is a system of thought that is mechanistic in nature (Ogunniyi, 1988; Jegede, 1997). It is based on things and seeks empirical laws, principles, generalizations and theories (Jegede, 1997; Ogunniyi, 1988).

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

Border Crossing Theory

Aikenhead (1996) has considered students' experiences with school science in terms of students "crossing borders" from the subcultures associated with his/her socio-cultural environments into the subcultures of science. He has used four types of border crossing between the student's traditional worldview and that of school science, namely: smooth, managed, hazardous, and impossible border crossings. Smooth border crossing occurs when the students' worldviews are congruent with school science. Managed border crossing occurs when the students' worldviews are different from the science worldview thus requiring the transition from one from one to the other to be managed. Hazardous border crossing occurs when the students' worldview and scientific worldview are rather diffused leading to hazardous transitions from one worldview to the other. Impossible border crossing occurs when the students' worldview and that of science are highly

discordant causing the students to resist transitions from one world-view to the other.

Collateral Learning Theory

Jegede (1995) has proposed the Collateral Learning Theory as a mechanism to explain how a student harmonizes the conflict resulting from a traditional worldview and that of science. He asserts that a student 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) 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. 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 world-view 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 learning fits between parallel and dependent collateral learning. It is a situation 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.

Even though the Collateral Learning theory has aptly identified the different types of collateral learning experienced by a student, it has, however, not described how the student acquires each one of them. It is also not clear whether a student remains fixed in one type of collateral learning or he/she can move from one to the other, depending on the concept being learned

Border Crossing and Collateral Learning

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. 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.

Contiguity Learning Hypothesis

Ogunniyi (2002) posited the Contiguity Learning Hypothesis as an explanatory model for cognitive border crossing. The hypothesis depicts border crossing as a dynamic rather than a fixed process. 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 student as well as his/her entire body are involved in the process of learning. It assumes that a student'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.

Aim of study

The study sought answers to the following questions:
1. How applicable are three cognitive theories/hypotheses (i.e. border crossing, collaterality and contiguity) to students' conceptions of force, energy, work, and power?
2. Can a Cognitive Border Crossing Learning Model (CBCLM) be developed using the Border Crossing, Collateral Learning and Cognitive theories/hypothesis?

Research design

The study described in this article was part of a larger study that had used a quasi-experimental design involving three schools in that the subjects were from intact classes rather than selected through randomisation. (Cohen, Manion & Morrison, 2000; Ogunniyi, 1992; Schumacher & McMillan, 1993). The schools were selected because they were all situated in the 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. Only the subjects from experimental group (A) and control group (B) were considered for this study. These consisted of 82 Grade 11 students whose ages ranged from below 16 years to above 23 years. School A consisted of 51 students of which 27 were males and 24 females. School B had 31 students of which 19 were males and 12 females. All of the students had been exposed to scientific and traditional worldviews through their interaction with a traditional community and through the science lessons and had also been exposed to an intervention designed specifically for this study.

The intervention consisted of a socio-cultural instructional model (SCIM) that integrates indigenous knowledge with school science on the students' conceptions of force, energy, work and power. The SCIM was based on the recommendations from different studies that were incorporated into the lesson plans. These included, among others, the idea that:
1. Generating information about the student's everyday environment to explain natural phenomena (Jegede, 1995; Manzini, 2000)
2. Teaching/learning materials that are simple, relevant to the context, and matching the developmental level of the students should be provided (George, 1999)
3. Class discussions should include considerations of worldview cultural perspectives and other more metaphysical concepts (Lawrenz and Gray, 1995)
4. The time for discussion in class should be increased because of the differences in the perceptions of the students (Lawrenz & Gray, 1995)
5. The teaching manner and style should
   a) Provide intellectual independence thus respecting the students as thinking individuals (Proper *et al.*, 1988)
   b) Encourage active observation, interpretation, and explaining on the part of the students (Proper *et al.*, 1988)
   c) Be accompanied by exposure to a variety of alternative modes of explaining so that the students would test their views against other views (Proper *et al.*, 1988)

To answer the first research question, the students were asked at the end of the instructional intervention to debate amongst themselves their views on certain phenomena. The students' discussions were video recorded and analysed using the three constructs. The aim was to test whether or not the students' 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, i.e. 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 students by the researcher at the end of which questions were asked that gave the students the opportunity to express their views freely. For the purposes of this study, the students' responses to the second and eighth questions, which were the only relevant questions of a pre- and post-test of a Physics Achievement Test (PAT), were also used in the analysis. The PAT had been used in the larger study and its data have been analysed elsewhere.

In order to answer the second research question and based on the results of the first question as well as literature, the researcher explored different ways of combining the three theoretical methods described earlier so as to come up with the CBCLM.

Applicability of the three theoretical constructs
Before developing the Cognitive Border Crossing Learning Model (CBCLM), the researcher had to ascertain whether or not Aikenhead's (1996) Border Crossing theory, Jegede's (1995) Collateral Learning theory and Ogunniyi's (1995) Contiguity hypothesis were applicable to the students' cognitive border crossing into school science. 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 two selected questions of the Physics Achievement Test (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 as none of the students demonstrated smooth border crossing —i.e. their worldviews were not congruent with that of school science.

Applicability of Managed Border Crossing
Some of students' comments in the group discussion 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. The first story is about a girl who fell while pushing a wheelbarrow containing water containers. Some of the students were able to explain the situation using the principle of moments, which states that the sum of the clockwise moments will only be equal to the anti-clockwise moments in cases of equilibrium. 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.

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 second story deals with a man who had an inefficient electric saw. Some of the students' responses also seemed to reveal that border crossing had been somewhat managed. The students 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 students' 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 what the witch doctor told him because when something is less efficient it uses a lot of energy to produce something less ... The saw was less efficient. Full stop.

I think the electrical saw cut not many trees just because he had thought of not changing oil ... 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 seemed to be considerable evidence of managed border crossing though sometimes expressed in an incoherent way. There was a sense in which the students could 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.

Applicability of Hazardous Border Crossing
Some of the students' responses to the different phenomena seemed to reveal some hazardous transitions in that their explanations were a mixture of scientific and alternative conceptions. In story one, certain alternative conceptions emerged as the students attempted to explain the whole incidence in a scientific way. They 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 those of moments of a force. Others 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 short 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.   (Excerpt from videotaped discussion)

The above responses seemed to reveal that there was some hazardous border crossing whereby the students' traditional worldview and scientific worldviews are diverse, thus leading to a sort of hazardous transition. Further, the responses seemed to suggest that the students 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.

The discourse that took place in story two, also revealed some alternative conceptions and/or misconceptions regarding the phenomenon. Some of the students 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 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.

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 seemed evident that the students had undergone a hazardous border crossing from their traditional world-view into that of school science. They seemed not to want to appear stupid at school, and so were motivated to do as well as they could, but their weak academic ability tended to have limited their chances of success in school science.

Applicability of Impossible Border Crossing

An incident recorded in the video discourse indicated that no border crossing had taken place in some of the students' minds. In other words, these students 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 students 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 that some of the students 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 are said to dwell near rivers amongst boulders and reeds and can only be seen by children who have not reached the stage of puberty. Some of the responses below illustrate this point quite vividly:

I think this botikoloshe contributed to the Zandile's fatigue ... 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 happened if she obeyed that instruction she must not bring water at night.

(Excerpt from videotaped discussion)

Secondly, some of the students' responses to story two seemed to also reveal that border crossing had probably not taken place in some of the students' 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 thought otherwise. The following argument from the videotaped discussion ensued between two students:

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: *Not exactly on that chain saw. The spirits affect Mr. Ngwenya the one that used the saw ... It might be Mr. Ngwenya didn't put the fuels because the evil spirits were working within him*

From the foregoing, it seemed that Sipho strongly believed in evil spirits that can be conjured by ancestors for punishing human beings. He and a number of the students 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?

Applicability of Parallel Collateral Learning and Managed Border Crossing

The post-test results for the PAT seemed to reveal that although 83% of the students 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 indicated that their traditional worldviews had not changed even after the intervention. Question 2.2 asked the students to explain why water should not be brought into a Swazi homestead after sunset. Question 2.3 required the students to describe what would happen if the rule of not bringing water into a homestead after sunset were broken. Two students (S_5, S_6) 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*

* By spokes, subject S_6 meant ghost (spook).

It is interesting to note that the above students wrote similar comments in the post-test:

S_5: *It's 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*

As can be seen from the above, the students responded using statements dealing with magic, mysticism, metaphysics, parapsychology, pseudo-science, and spiritism both at the pre- and post-test stages. These results seemed to suggest that: although a considerable number of the students 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), they, however, continued to adhere to their traditional worldviews before and after the tests with regard to Q2.2 and 2.3. This could also be viewed as an evidence of parallel collateral learning since the students' conflicting schemata seemed not to interact at all. They seemed to mobilize a particular worldview they thought was appropriate for the occasion.

From the foregoing, it is reasonable to conclude that the relationship between parallel collateral learning and managed border crossing seemed to have been demonstrated. The students 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 had been managed and not smooth since the worldviews of the students and those of school are not congruent.

Applicability of Secured Collateral Learning and Managed Border Crossing

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 witchdoctor's 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. 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.*

When applying Jegede and Aikenhead's (1999) claim on the relationship between secured collateral learning and managed border crossing to the above excerpt, it seemed as if Langa managed to cross the border between his traditional worldview and that of school science. This was because he was able to explain, using scientific concepts, that the saw's inefficiency produced less work. However, he appeared to consciously hold on to his traditional belief that the Inyanga had bewitched Mr. Ngwenya by putting 'the spirits of forgetting on him', thus exhibiting secured collateral learning.

Applicability of Dependent Collateral Learning and Hazardous Border Crossing

Some of the students 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 seemed 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 (dependent collateral learning):

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*

An examination of the above excerpts seemed to illustrate Jegede and Aikenhead's (1999) claim that there is a relationship between dependent collateral learning and hazardous border crossing. The two students seemed 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.

Applicability of Contiguity Learning in a traditional worldview-dominated context

Ogunniyi (2002), 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 student 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. Therefore the variety of experiences to which a student is exposed within a day may trigger off different schemata in given instances, depending on the dominating worldview at that particular point in time. What seems imperative is how the student adapts to the flux of change in his/her contextual circumstances. Therefore a student in a traditionally dominated context may 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 of the students (S_{16} and S_{17}) from group A, 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 students' comments in the pre-test were as follows:

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 and 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 students' 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 could be assumed that the above students 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, 2002). In other words, these students 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, 2002). What is more, it would be reasonable to assume that the behaviour exhibited by the above students could have been a result of traditional worldview influence from the other students in the group during the period between the two tests, basing it on the fact that the context of group A was mainly dominated by a traditional worldview as illustrated by the students' presuppositions in the following excerpt from the videotaped group discussion:

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.*

From the above excerpt, it was evident that most of the students, 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.
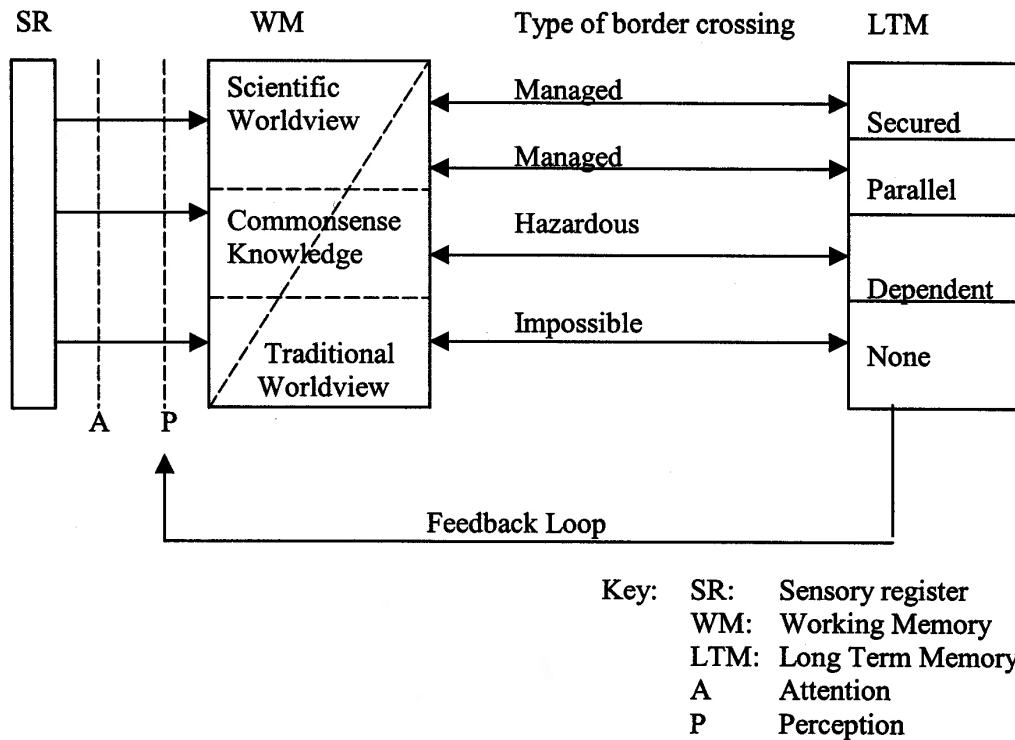
Figure 1 The Cognitive Border Crossing Learning Model (CBCLM)

Applicability of Contiguity Learning in a scientific worldview-dominated context

The context for the videotaped group discussion for the students in C_2 was dominated largely by the scientific worldview presupposition. Most of the students, except Langa (cited earlier), tried to explain both phenomena using a 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. The predominantly scientific context caused him to agree to both worldviews, hence confirming Ogunniyi's (2002) argument 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.

Applicability of Contiguity Learning, the interest shown and human interest

While 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 (2002), 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 during the learning endeavour, in this case, during the group discussion. This interest probably caused 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, 2002).

Developing A Cognitive Border Crossing Learning Model (CBCLM)

After verifying the applicability of the constructs, the researcher observed that each of the constructs described above could not fully capture the process of border crossing when treated separately. A question arose as to whether the three constructs could be combined to come up with a model that could show how, when, and under what conditions the various types of border crossings and collateral learning might occur within the mind of students as they try to move from one worldview to another. Therefore, a Cognitive Border Crossing Learning Model (CBCLM) was proposed, which combines the three theoretical constructs: Aikenhead's (1996) Border Crossing; Jegede's (1995) Collateral Learning, and Ogunniyi's (1995) Contiguity Learning.

Features of the CBCLM

The CBCLM (Figure 1) uses the information-processing model depicted by Eggen and Kauchak (1994) and Johnstone (1997) as its basic framework. It is divided into three main parts: the Sensory Register (SR), the Working Memory (WM), otherwise known as short memory, and the Long Term Memory (LTM) that are joined by arrows.

The learning process in terms of the CBCLM

This section illustrates how the CBCLM can be used to describe how a scientific concept presented in a science classroom is learned or rejected by a student.

Receptors and Sensory Register

When stimuli from a science classroom environment enter a student's Sensory Register (SR) through receptors, the context of the scientific phenomenon being presented activates his/her schemata. These schemata are mental structures that represent the student's internalised and organised knowledge of the world (Moates & Schumacher, 1980). The student will pay attention and start to perceive the scientific concepts being presented by attaching meaning to the information received from his receptors by using prior knowledge and experience. The resultant worldview schema will then be transferred to the Working Memory.

Contiguity Learning within the Working Memory

The Contiguity Learning hypothesis is used in the Working Memory. The diagonal line across the Working Memory box shows the divide between traditional and scientific worldviews. The area in each section is proportional to the dominating worldview, i.e. the bigger the area the more dominant the worldview. The two horizontal lines within the WM box show the division between the commonsense-intuitive knowledge and the other two worldviews. The area within this section is proportional to each worldview, i.e., the commonsense-intuitive knowledge is dominating, whilst the scientific and traditional worldviews are equal but recessive.

When the perceived worldview schema from the sensory register enters the Working Memory (WM), it lies contiguously with two or more other worldviews (traditional and/or commonsense-intuitive knowledge) that have been retrieved from his/her LTM via the feedback loop. 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 student's indigenous beliefs as well as his/her commonsense-intuitive knowledge are contrasted with the 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 (2002), a given context triggers off the worldview schemata in the student resulting in a corresponding worldview schema gaining dominance over the others within the student's cognitive structure. 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. The success of this integrative and transformative cognitive process is what Ogunniyi (2000) calls Contiguity Learning.

Border Crossing and the transition between WM and LTM

The Border Crossing theory is used in the transition between the Working Memory and the Long Term Memory. The arrows between the WM and LTM illustrate the various types of border crossings that can occur when information is transferred from the WM into the LTM. According to Fakudze (2002), the level of success of the integrative and transformative cognitive process determines the type of border crossing that will take place in the transition between the WM and the LTM. One of the following border-crossing intellectual postures will be attained:

- Managed border crossing would occur when the scientific worldview schema is dominant;
- Impossible border crossing would occur when the traditional worldview schema is dominant;
- Hazardous border crossing would occur when the worldview schemata have gained more or less equal supremacy (i.e. none of

the schemata is dominant but all two or three are evident) or where the commonsense-intuitive schema is dominant.

According to Ogunniyi (2002), it is the quality or strength of the experience that predisposes a student to exhibit a particular type of border-crossing mentality.

Collateral Learning within the Long Term Memory

The Collateral Learning theory is used in the Long Term Memory. Once the information passes from WM into the LTM, some permanent storing begins through the encoding process. The encoding process and storage depends on the type of border crossing (Aikenhead, 1996) that took place in the transition from the WM. The storage takes place in the form of Collateral Learning. The different types of collateral learning are represented in four sections, for instance:

- Parallel or secured collateral learning occurs when the border crossing was manageable, i.e. the incoming information could be linked to a reasonable number of networks already in existence in the LTM. The incoming encoded information will find a good fit to existing knowledge in the LTM.
- Dependent collateral learning occurs when the border crossing was hazardous, i.e. only a few networks could be linked, resulting in misconceptions and/or alternative conceptions. The incoming encoded information will find at least a good fit with the existing knowledge. In other words, the thought systems will match partially, resulting in a misfit.
- No Collateral Learning occurs when none of the networks could be linked as a result of impossible border crossing. The student would have failed to attach it to the existing information in his/her LTM. No collateral learning will take place resulting in the rejection of the incoming information. The student would stick to his/her traditional worldview presupposition regarding that particular concept.

Conclusion

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 seemed 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.

The CBCLM described in this paper appears to be a feasible way of describing how a student shifts from one worldview to another during the learning process. Needless to say, 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 (2002) 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 CBCLM, which were proposed by the present study.

Also, it is apposite to state that the information-processing model depicted in the CBCLM was found to be only one 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 program as the information processing models seem to suggest (Searle, 1984; Moore, 1998)?
- Is the mind located in the brain or elsewhere in the body (Szasz, 1996; Cobb, 1994)?

• Are mental processes caused by certain physico-chemical elements and metaphysical schemata in the brain or not (Ogunniyi, 2002)?

All these questions show the complexity of the mind-body controversy, which, unfortunately, is beyond the scope of this study.

Implications of the findings

The findings of this study have several implications for science education. Firstly, there seems to be a need for a science curriculum that would require a science education perspective that views science learning as a process of crossing the boundary between the students' worldview and science worldview (George, 1999), as has been illustrated in the results of this study. Secondly, this type of curriculum approach requires teachers to understand the students' fundamental, culturally based beliefs so as to teach a kind of science that coincides with the intellectual interest and socio-cultural setting of such students. Science teachers should become aware of the impact of cultural variables such as traditional beliefs and religious affiliations in their teaching efforts (Jegede & Okebukola, 1991); they need to increase the amount of discussion that takes place in the science class. (Cobern, 1996; Lawrenz & Gray, 1995). Thirdly, this implies that teachers and curriculum developers, especially 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 students in a way that would take into account the students' cultural beliefs (Ogunniyi *et al.*, 1995; George, 1999; Proper *et al.*, 1988). Fourthly, several studies (Allen & Crawley, 1998; Kawagley *et al.*, 1998) have shown that a curriculum that is not sensitive to the students' cultural background tends to produce passive students. To alleviate the consequences of such a curriculum, the students should not be made to abandon their cultural background knowledge for conventional science, but instead are encouraged to adjoin the two worldviews.

Needless to say, a lot of research is still needed to investigate the learning processes taking place within a science classroom.

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