Collateral Learning in Science:
Students' Responses to a Cross-Cultural Unit of Work

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Abstract

The purpose of this study was to investigate the nature of students' responses to a cross-cultural science unit entitled "Maintaining health," which was designed to help students to build bridges between their traditional practices and beliefs and western science concepts. This paper reports on students' responses to a pre-test and post-test and on their reflections on the lessons and the unit. The responses were analysed using Jegede's (1995) collateral learning model, and they provided evidence of parallel, dependent, and secured collateral learning. The implications for the assessment of science learning are discussed.

Key words: collateral learning, cross-cultural science curricula, border crossing

Introduction

The dominant view of science during the 1960s and 70s was as a universal, value-free, objective way of knowing. During the late 1980s and 1990s, however, the view of some researchers (Aikenhead, 1996, 1997; Baimba, Katterns, & Kirkwood, 1993; George, 1995; Hewson, 1988; Jegede, 1995) that science may be conceptualized as a subculture of western societies--a way of thinking circumscribed by the norms, values, beliefs, and actions of a sub-group within western societies--became quite prominent. Proponents of the cultural view of science contend that science is a unique way of thinking that often requires students, especially those from non-western societies, to cross boundaries from their culture into the sub-culture of science.

The view that science is culture and**,** correspondingly**,** that science learning is culture acquisition has become prevalent during a period of widespread reform in science education. In this climate of reform, science teachers are being asked to rally around the clarion call of "Science for All" by emphasizing the relevance of science curricula for everyday living. Therefore, there have been calls for "multicultural science curricula" or "cross-cultural science curricula" (Aikenhead, 1997; George, 1995; George & Glasgow, 1999; Hodson, 1992; Jegede, 1995; Snively & Corsiglia, 2000; Waldrip & Taylor, 1999), and culturally relevant pedagogy (Ladson-Billings, 1995). The thinking is that these curricula would operationalize the traditional Ausubelian principle that teaching must begin where the learner is. This means that science teachers must be cognizant of the students' prior knowledge about topics being addressed and that they must use this knowledge in the classroom during science teaching.

Investigations into students’ prior everyday knowledge about matters that are often addressed in science classrooms began in the Caribbean with the pioneering work of George (1986) and George and Glasgow (1988). George (1986) recognized that traditional customs and beliefs were a part of students' prior knowledge, and she used the term "street science" to describe these traditional customs and beliefs. Later, George (1995) continued research work in this area, and she conducted an in-depth study of the traditional practices and beliefs of persons who resided in a rural community, "Seablast," situated in Trinidad and Tobago. She discovered that traditional practices and beliefs constituted the prior knowledge of many persons who resided in "Seablast." For example, George (1995, p. 93) discovered that "one of the principles that is still fairly prominent is the principle relating to heat and cold. A 'heated' human body should not be exposed suddenly to cold environments." She also found “a system of practices which acknowledges food as being essential for the functioning of the human body but which also acknowledges that food contributes to body dysfunctions. The cycle of ‘cooling/ purging/building-up’ is based on this principle" (p. 112). George (1995) induced that these traditional principles undergirded the practices of many villagers of Seablast.

George’s (1995) findings provided empirical evidence that the students who live in and attend school in Seablast are exposed to traditional beliefs about many health-related issues that are addressed in the formal science classroom. In accordance with cognitive learning theories, the traditional beliefs can impact on students’ understanding of conventional science concepts. In principle, then, any unit of work, which is designed for students who reside in Seablast and which addresses health-related matters, should take the traditional ideas on board. For example, a traditional belief is that mismanagement of the ‘heated’ body causes the common cold, but this concept is not mentioned/discussed in the formal science classroom as the students are exposed to the western science concept that a virus causes the cold. George (1995) advocated further research into science teaching/learning that takes account of students’ prior traditional knowledge.

In response to this suggestion, I developed a unit of work entitled “Maintaining Health” for students who attended Seablast Secondary. During the enactment of the unit, the students' traditional practices and beliefs were used as a springboard from which they could build bridges to conventional science concepts. The bridge-building device used in enacting the unit was the explicit comparison of health-related traditional practices and beliefs with conventional science concepts, in terms of similarities and differences and strengths and weaknesses.

The purpose of the study was to explore the nature of the students' explanations of health-related phenomena when exposed to a cross-cultural unit of work. This paper reports on students’ explanations prior to, during, and after the enactment of the cross-cultural unit of work.

Theoretical Underpinnings

In the new thrust towards science for all, educators have proposed a variety of innovative ways to make the science curriculum relevant to an increasingly diverse student population. Many of these innovations have been undergirded by cognitive theories of learning and by constructivism as a way of thinking about the nature of knowledge. These theories of learning and of epistemology have the common premise that students' prior knowledge is a perceptual lens through which incoming experiences are filtered, as they attempt to make sense of phenomena.

An implicit aim of many of the instructional approaches in science education that are based on cognitive theory has been conceptual change (Posner, Strike, Hewson, & Gerzog, 1982). Conceptual change has also been equated with conceptual exchange, and, within this framework, the main criterion of successful science instruction is that students would have replaced their prior concepts with the currently accepted western science concepts. One disadvantage of the conceptual change (exchange) model is that science teaching is often viewed as an attempt to assimilate minority groups into the dominant western science worldview. Many years of research, however, have revealed that the students' prior conceptions are very resilient (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Solomon, 1983, 1987), and this finding is often interpreted to mean that the students have not accessed the conventional western science concepts that were presented in the classroom.

In 1995, Jegede put forward a model of learning that he termed "collateral learning," which provides an alternative to the conceptual (ex)change model as a way of describing the learning outcomes when students, particularly those from non-western societies, are exposed to the culture of science in the formal classroom. Jegede (1995, p. 117) defined collateral learning as "an accommodative mechanism for the conceptual resolution of potentially conflicting tenets within a person's cognitive structure." Jegede proposed four types of collateral learning--parallel, dependent, simultaneous, and secured- that fall on a continuum in which parallel collateral learning and secured collateral learning are on opposite poles. Parallel collateral learning is said to occur when students hold conflicting concepts in long-term memory. There is no interaction between these concepts and they are used in different contexts. Secured collateral learning, on the other pole, occurs when there is conscious interaction between conflicting schemata. There can be either a restructuring of the schemata in which there is "convergence towards commonality by one schema reinforcing the other" (Aikenhead & Jegede, 1999, p. 278), or persons can be aware of both schemata and have an adequate reason for maintaining both sets of concepts. Dependent collateral learning results in an amalgamation or a "well stirred mix" of ideas. The fourth type, simultaneous collateral learning, is the term used when both sets of concepts are learnt at the same time and they reinforce each other.

The collateral learning model is consistent with the view of science learning as “border-crossing” (Giroux, 1993), which is a useful metaphor whenever alternative ways of knowing/explaining selected phenomena are identified. This metaphor captures the idea that there are domains of knowledge specific to various cultural contexts and that excursions from one way of knowing to another can occur as attempts are made to explain phenomena. Those who adopt the collateral learning model often view science learning as autonomous acculturation (Aikenhead, 1997). Researchers such as Jegede (1995), Aikenhead (1997), and others posit that the latter thinking is more appropriate for science curricula to which First Nation Peoples and persons from developing countries are exposed than is assimilation. With autonomous acculturation the students' prior knowledge is honoured and, at the same time, the students can benefit by accessing the cultural capital of western science, as they see fit.

Trinidad and Tobago is normally classified as a developing country where a range of traditional explanations is juxtaposed against western science explanations. These conditions seemed to favour the adoption of the cross-cultural approach to the design of science curricula and collateral learning as the possible outcome of these experiences. The collateral learning model has been applied successfully to research findings that have been reported in the literature (Aikenhead & Jegede, 1999), and is also evident in the work of researchers such as Ogawa (1995) and Ogunniyi (1988). I therefore felt that this study would further our understandings about border crossing and collateral learning.

Procedure

This instrumental case study (Stake, 1995) is located within the qualitative paradigm. The students who comprised the case were members of a class of 40 students who were between the ages of 12 to 17 years.

The students were exposed to a unit of work entitled "Maintaining Health." The unit consisted of five lessons entitled *"Cold or Not?" "The common cold: Catch me if you can," "Cooling-Off," "Cooling: A home remedy,"* and *"Pimples and the adolescent."* The lessons were designed to utilize the traditional principles that were identified by George (1995) and which underpinned the management of the “heated” body. I assumed that the induced principles underpinned students' prior knowledge, and my intention in developing the unit was to help students to build bridges between the traditional practices and beliefs and the western science concepts. The lessons were enacted for one session per week over a period of 8 weeks, and each session lasted for 90 minutes.

Prior to, and at the end of the unit, the students were given a written test, which comprised two main types of items. In one type, the students were asked for their personal explanations for health-related phenomena, by explicit use of the term "*you*," for example, "*how would you explain how people catch the cold?*" This item was meant to elicit the explanation that the student had accepted before and after exposure to the unit of work. The pre-test and post-test responses were compared to determine if there were changes in students' personal explanations. In other items, the students were provided with explicit cues that were intended to elicit the western science explanation. For example, in the latter type of items, the terms *"the science teacher"* and *"the science textbook"* were used to provide the western science context. These latter items were intended to provide opportunities for students to demonstrate that they had accessed the conventional science concepts, even if they did not necessarily accept them as their personal explanation. In some cases, the item comprised stimulus material that was contextualized within a framework of traditional practices and beliefs, and the students were cued for either personal explanations or for western science explanations.

In addition, students were given opportunities to reveal their understanding of the concepts during small group discussions within the class session, and to comment in writing on their understanding at the end of each lesson. Post-unit interviews were also conducted with a focus group of students to gain further insights into the learning process within the context of a cross-cultural science unit.

The pre-test and post-test data were analysed qualitatively for patterns and trends as well as for changes in explanations, and the in-class discussion data and data from the focus groups were analysed for patterns and trends**.** The findings from two (the first and the last) lessons: *"The common cold: Catch me if you can"* and *"Pimples and the adolescent"* are presented below.

Findings

Overview

Analysis of the pre-test results indicated that the majority of students used only traditional concepts in explaining the occurrence of the common cold. However, in responding to the items based on the concept of "Pimples and the adolescent," some students employed conventional science concepts and/or their everyday common-sense constructions. For example, the conventional science term "puberty" was used along with everyday notions that dirt is a contributing factor in the appearance of pimples. Few students referred explicitly to the traditional belief that pimples appear when there is excess "heat" in the body (George, 1995).

A comparison of the pre-test responses with those on the post-test indicated that some students had accessed many of the conventional science concepts that were presented in the class. They had learnt science. However, the learning was demonstrated in different ways as secured, dependent, and parallel collateral learning, and the science concepts were elicited in different contexts. Students' responses to items based on the lesson *“Pimples and the adolescent”* provided evidence of secured and dependent collateral learning. As an example of the former, the responses showed that some prior ideas were restructured. There was a change from explanations that contained a mixture of traditional/everyday concepts and conventional science concepts about *"Pimples and the Adolescent"* to explanations that drew upon conventional science concepts only--an indication of secured collateral learning. The students demonstrated that they had constructed a new conception in long-term memory**.** The post-test explanations reflected a convergence between those aspects of the pre-test explanations that were rooted in conventional science and the conventional science concepts that were presented in the classroom.

Examples of parallel collateral learning and dependent collateral learning were evident from students’ responses to the lesson entitled *“The common cold: Catch me if you can.”* Their explanations included ideas from both worldviews, and were elicited in relation to the context within which the item was framed. For example, the traditional practice or belief was presented as personal explanations and the western conventional science explanation was given when students were cued specifically for the science explanation. These latter findings were examples of parallel collateral learning. When cued for personal views prior knowledge was used, but when cued explicitly for the western science explanation, the appropriate western conventional science concepts were produced.

Dependent collateral learning was the outcome of lessons when students’ responses to a single item contained a mixture of ideas from both worldviews.

The details of the analysis of students' explanations are presented below, beginning with examples from the lesson entitled *"Pimples and the adolescent."* Immediately following are examples from the lesson *"The common cold: Catch me if you can."*

Secured Collateral Learning: Restructuring Schema

The comparison of the pre-test and post-test responses based on the lesson entitled *"Pimples and the adolescent"* revealed that some students built on their prior conventional science notions to construct a fuller explanation of the phenomena discussed. One student's response illustrates. In response to the item in which a personal explanation about the cause of pimples was requested, the student's response shows a restructuring of the original explanation that puberty and dirt were both factors that contributed to the appearance of pimples. On the post-test, the student revealed a fuller understanding of the conventional science explanation of puberty by including the conventional science concepts of the role of hormones and bacteria. The student retained the scientific notion of puberty that was mentioned on the pre-test. However, the concrete causal factor (dirt) was replaced by the abstract ideas that hormones and bacteria were involved in the appearance of pimples:

> *Your young brother says: "I don't understand why you have pimples on your skin." Write what you would say to explain to him why you have pimples.*
>
> > Pre: Because when someone grows old they come into the stage of puberty. From dirt left on your skin. And everyone goes through a stage of puberty. And puberty is harsh on some people. **(No 24)**

> Post: I have pimples because it's a part of growing up when you reaches the stage of puberty there are changes in your body. The hormones and bacteria reacts to your body. **(No. 24)**

The pre-test and post test also contained an item in which there was an explicit cue for the science explanation: *Let's tell you the reason that our science teacher gives for the appearance of pimples.* Interestingly, the student did not use the conventional science term "puberty" that had been included in the personal explanation. The explanation was based solely on the notion that pimples are caused by the presence of dirt on the skin. At the end of the unit, however, the science explanation was similar to her personal explanation. There was convergence towards commonality in personal explanation and science explanation:

> Pre: Pimples is left on the skin by excess dirt on the skin stage of pimple. **(No. 24)**
> Post: The hormones in your body and the bacteria reacts to the germs in your body and when you're growing up and you reach the stage of puberty you get acne. **(No. 24)**

For the student, then**,** whose prior knowledge comprised both conventional science ideas and everyday knowledge, the outcome was a restructuring towards conventional science. In contrast, for students whose prior knowledge comprised everyday beliefs only, the outcome was dependent collateral learning**--**a well-stirred mix of ideas. Examples of dependent collateral learning are illustrated below.

Dependent Collateral Learning

In response to items based on the lesson entitled *"Pimples and the Adolescent,"* which contained a personal cue, there was evidence of a change from traditional explanations to mixed responses:

> Pre-test: When there is dirt left in the skin**. (No 13)**
> Post-test: Pimples appear when people reach the stage of puberty or adulthood and when you eat junk or fast food. (No 13)
>
> Pre-test: Well I get pimples on my skin sometimes when I'm feeling very hot and when I eat plenty pepper**. (No 25)**
> Post-test: I would tell him that I have a lot of pimples on my face because I eat a lot of junk; I eat a lot of pepper; I may have germs**. (No 25)**

Other post-test responses revealed mixed constructions. For example:

> People get pimples when you are growing into a teenager. You start to develop physically and you change. Sometimes you get pimples when you are not taking a regular cooling or your body need to be washed out from all the stuff that you eat that gives you pimples on your face. **(No 23)**
>
> Well pimples does be by dirty blood and like you become a teenager you tend to get pimples on your face. **(No 11)**

There was no evidence of parallel collateral learning in students' responses to the topic of pimples and the adolescent.

Parallel Collateral Learning

Evidence of parallel collateral learning emerged during discussions in class. After the explicit comparison of the temperature theory and the germ theory of explaining the common cold, the small groups of students were asked to discuss the following question. What advice would you give to persons so that they can avoid catching the common cold?

As I monitored these discussions among students, I recognized that the first explanations that the students' provided drew upon their traditional practices and beliefs**:**

> Not to go and play in the sun and then go and bathe. Cool out first**.**
>
> Not to bathe when they body hot or not to bathe when they were playing in the sun or they mustn't go in the bathroom when they not get up. When the body hot not to mix with cold.

However, while requests for personal explanations cued the traditional practice or belief, my intervention during the discussions cued the scientific way of thinking as another source of explanation. The excerpt below reveals that my prompt provided the context in which the students recalled that person-to-person interaction can result in the cold:

> S: Some people catch the cold by when they get up they will not cool out before they go and bathe. Some will as (soon as) they get up they will go in the bathroom barefooted on the cold concrete, and as (soon as) they come from the sun playing they will go and jump in the bathroom**.**
> T: That's it?
> S: Ahm what again? Like the scientists say. Well if someone have the cold they will catch it, catch the cold, yeah!

Two items on the tests also provided evidence that the some students had engaged in parallel collateral learning. In one item, the stem comprised the traditional beliefs about the cause of the cold**,** and the task cued for a personal explanation about the cause of the common cold**.** On the pre-test and post-test, the students' responses were based upon the traditional concept that a sudden temperature change caused the cold. Students attributed the cold to, for example, the effects of water and the effect of moving from the sun to the fridge without the precaution of "cooling out." The following examples illustrate the responses of two students, which were characteristic of the group**:**

> *How would you explain how people "catch the cold?"*

> Pre: People catch cold by staying in the water too long. As you come from in the sun you sometimes go in front of the fridge. Ironing then bathing (with the coal pot iron). As you get up you take a shower without cooling out yourself. **(No 24)**
> Post: Some people catch the cold by getting wet in the rain and doesn't dry their hair properly. After ironing going and bathe in cold water. After waking up and taking a cold shower right away. **(No 24)**

> Pre: That is how I got my cold. By going and bathe in very cold water. By drinking too many cold drinks like ice water. By bathing in the rain and you are sick with fever, you get more fever and cold at the same time. **(No 27)**
> Post: I will explain to people how they catch the cold when the cold of the atmosphere touches your body it makes you body comes cold and you might catch the cold because your body is always hot. **(No 27)**

However, when a conventional science cue was used, the students demonstrated that they had accessed the conventional science concept that germs cause the cold. In response to the item- *During science class, Kevon read an explanation from his science textbook of how people catch the cold. Describe what might have been written in the science textbook.* The responses from the same students as above were as follows:

> Pre: They will tell you ways people get cold. Like playing in the rain long and without drying your hair properly. Sneezing, wheezing and coughing. Having a sick feeling. **(No 24)**
> Post: It might have said by transferring or giving someone the cold. Like when someone sneeze and doesn't cover their mouth the germs from them is spred to other individuals. **(No 24)**

> Pre: What might have been written in the science textbook are like people who get up early in the morning and go outside without putting on your slippers. Going and playing in water too long. After playing in the sun going and bathe in the shower or after bathing and going to sleep with your hair wet. **(No 27)**
> Post: what might have been written in the science textbook are people get the cold by a virus or germs. Because people don't always get cold by ironing and then going in the refrigerator or sleeping with wet hair. **(No 27)**

Taken together, the responses show that the personalized cue triggered the traditional beliefs. But as shown above, for some students the traditional belief was not used on the post-test when the science context was established explicitly. For other students, however, the post-test responses provided evidence of dependent collateral learning. The following illustrate:

Dependent Collateral Learning

Though in the minority, when the science context was explicitly established, some students' explanations on the post-test represented a well-stirred mix of ideas. The students included the conventional term "the virus" in their explanations or expressed the idea that the cold is spread from one person to another. For example:

> People catch the cold by bathing in the cold river on mornings to go to school, or by someone else. **(No 12)**

> People catch the cold by going to the refrigerator after playing in the sun or after ironing that also causes the virus**. (No 33)**

There were also instances of dependent collateral learning on the post-test in response to personalized cues:

> People catch the cold from people or they get it from things they do like bathe late and not dry they hair properly**. (No 23)**

> People get cold by getting wet in the rain and having a cold shower as soon as they get up from sleeping and they causes them to get the cold they called virus**. (No 33)**

> I think people catch the cold when your blood is heated or like you take a bath. The cold water and your body is heated would not agree and you could catch the virus or the bad cold. **(No 10)**

Students' Reflections On Their Learning.

To gain further insights into the learning process when students are exposed to a cross-cultural unit of work, they were asked to write their reflections to guided questions at the end of class and to participate in end-of-unit focus group interviews. The following are some responses to the questions: What did I learn in science class today? How is what I knew before similar to what I learnt today? How is what I knew before different from what I learnt today?

At The End Of Class: The Common Cold

I always know that using hot and cold you can catch the cold. What I learn today was similar**.**

In science class today, I heard things about the cold that I knew already, so it's just like doing it over. What I knew similar before was always put on a slippers after coming out of your bed in the morning and never walk in the rain.

You can get the cold from getting up from bed. You should not go on the cold floor.
When going in from the fridge while playing in the sun, your body temperature changes and you get the cold.
You could get the cold from someone else. I know now that a virus causes the cold.

That people get the cold after getting their bath and put their wet feet on the ground**.**
Head cold from not drying their hair**.**
You can get the cold from someone else.

At The End Of Class: Pimples And The Adolescent

I learn in class today reasons why people get pimples, and differences and similarities of everyday life to what scientists say.

I learn how we get pimples. That it is not through junk food

I learnt that the everyday view is oil, junk food and grease.

Focus Group Interviews

Students expressed the view that the use of the bridge-building approach to science teaching/learning exposed them to “the other half.” A member of one group said:

> I think it was helping you out. You know something before but like you didn’t get the whole piece of it. Like you know a half and you was teaching us de other half, like. Or sometimes you (are) missing a piece of something.

Based on students’ reflections, it is evident that their responses to the concepts presented in the two lessons were different. For the lesson on the common cold, students focussed on the similarities between their prior knowledge and the concepts discussed in the classroom setting. However, for the lesson on pimples, students concentrated on the differences between the everyday view and the scientific explanation, and their responses indicated that they rejected the everyday explanation that junk food is the cause of pimples. Students’ thoughts about my role in exposing “the other half” can serve as a possible explanation for instances of parallel collateral learning and dependent collateral learning identified. For some students, where there is incongruence between their prior knowledge and the scientific concepts presented, “the other half” could be interpreted to mean that different ideas could be elicited based on context (parallel collateral)**;** for others it meant that the science ideas should be included along with previous constructions (dependent collateral).

Overall Summary

At the end of the unit, there was evidence of parallel collateral learning and dependent collateral learning in students' responses to the items on the common cold. Upon presentation of contextualized stimuli, the request for personalized explanations triggered traditional responses about the common cold. On the other hand, explicit cues for the science explanation allowed students to demonstrate that they had accessed conventional science concepts about the common cold**,** even though they had used the traditional mode as their personal explanations. Parallel collateral learning occurred in cases where the students' original explanation was based solely on the traditional concepts, and the students' explanations changed in response to the type of cue.

The analysis also revealed that requests for personal explanations sometimes elicited the conventional science concepts. For example, in response to the items on the lesson entitled *"Pimples and the adolescent,"* some students restructured their original mixed explanations about the cause of pimples by focussing on the aspects of their explanations that were similar to the conventional science concepts and developing these conventional science explanations about puberty. These restructured responses indicated that secured collateral learning had occurred, and revealed that the explicit conventional science cue was not required to elicit the conventional science response. It was evident that restructuring of schema towards conventional science (secured collateral learning), whether cued as personal explanation or whether the science context was explicitly established, was the outcome of the lessons in which the student**s**' original explanations comprised elements of traditional/everyday knowledge and conventional science concepts.

The results of this study provided further evidence that the nature of students' prior knowledge impacted on their final responses.

Discussion

From this study, it is evident that the students engaged in border crossing from traditional ways of knowing and everyday constructions to conventional science understandings**,** and that they engaged in secured, dependent, and parallel collateral learning. It is plausible that collateral learning as a positive outcome because the pedagogy of bridge-building facilitated students' entry into the western science world. By engaging in the bridge-building strategy, the students interpreted the science explanations as "the other half." This is a significant finding in two ways.

Firstly, it illustrates a way of thinking about science that fits in with the concept of autonomous acculturation. It is very different from thinking about science as the "superior," only valid way of knowing--thinking that often underpins the scientism of many science curricula. Many students who are exposed to such science curricula often interpret science as attempts at assimilation and feel alienated from science (Aikenhead, 2001, 2006; McKinley, 2005). It is likely that students' interpretation that science is "the other half" may have fuelled their disposition to learn science.

Secondly the finding suggests that teachers of cross-cultural curricula should continuously engage participating students in discussion about their interpretations of their learning experiences. Teachers could then use the students' interpretations as a guide to help their students to develop fuller understanding about different worldviews by focussing on the differences between them. Discussions could center around the differences in philosophical underpinnings and in underlying values, and also on the role and purposes of each knowledge system in mediating people's understanding of themselves and their relationship to their environment. Such discussions may lead students to construct other types of relations between western science and traditional practices and beliefs that are different from "the other half." For example, in-depth discussions may allow students to discern the relationship between the worldviews as "different wholes," and could simultaneously facilitate border-crossing.

The students' disposition to cross borders, evidenced by including science concepts as a part of their explanations, contrasts with the case of "Coddy" reported by Aikenhead (2000a, p. 13):

> Coddy did not want to spoil his aesthetic understanding of nature's beauty by 'polluting' his mind with mechanistic explanations of Mother Earth's landscape. He understood science all too well, and chose not to cross one of its borders.

On the other hand, the results lend support to Aikenhead's (2000b) and (2006) reports, which respectively cited Cajete's and Barnhardt et al.'s findings that the cross-cultural approach to science teaching enhanced First Nation American students' understanding of western science. Aikenhead (2000b) also reported that Baker, and Ritchie and Butler who worked with Aboriginal students in Australia and New Zealand respectively had obtained similar results.

In sum, the Seablast students' interpretation of science as "the other half," which emerged from their exposure to the bridge-building strategy adopted in the cross-cultural science unit, is significant, especially so in a context in which students are expected to participate in democratic decision-making processes in societies that are increasingly dominated by western science ideas.

Aikenhead and Jegede (1999) note that border-crossing from one way of knowing to another is a complex process and that the results are often unpredictable. They report that some students integrate the forms of knowledge, which reflects a holistic worldview; for others, there is compartmentalization of knowledge--a reflection of multiple worlds. The complexity of the border-crossing strategy also arises because researchers/educators often have different goals for cross-cultural teaching. For example, Aikenhead and Jegede (1999) cite Waldrip and Taylor as advocating secured collateral learning that indicates a holistic view. On the other hand, they state that Lowe strongly supports parallel collateral learning and those secured collateral learners who are conscious of their multiple worlds.

Whatever the stance taken by researchers, students' explanations will reflect their understandings and, as this study shows, at the end of a unit of work the students' explanations may include their prior conceptions. There are implications of these views and the findings of this study for the assessment of science teaching/learning. The dominant view of science learning, underpinned by conceptual change theory, is that secured collateral learning is the only indication of science learning. But, it is evident from this study that students who are exposed to conventional science learning in the formal science classroom engage in dependent or parallel collateral learning when their prior knowledge is not congruent with the concepts presented. Perhaps the research community has paid too little attention to investigating students' access to science concepts, which is demonstrated as parallel or dependent collateral learning.

As illustrated above, according to the nature of students' prior knowledge, the manner in which questions that are based on contextualized stimuli are posed can determine the type of student response. When asked for personalized explanations about everyday experiences, like the common cold, students whose prior knowledge comprised only traditional practices and beliefs used their prior knowledge of sudden temperature change as the cause--an explanation that is not congruent with the conventional science concept of the virus discussed in class. Solomon (1992) cited Viennot's findings that students may revert to their prior knowledge when presented with contextualized or embedded stimuli. But in the present study, this type of response did not mean that the students had not learnt the conventional science concepts. When cued explicitly for conventional science, students presented the conventional science view that germs that are transferred from one person to another are the cause of the common cold.

It is evident, then, that teachers who are involved in cross-cultural teaching must decide if they are assessing whether the students have accessed the conventional science or if they have personally accepted the conventional science explanation. Ultimately, the purpose of the test will determine the manner in which the items are designed (the types of cues--personalized cues or explicit conventional science cues) and the manner in which the items are scored. For example, if teachers of cross-cultural units were assessing whether their students have accessed the conventional science concepts presented in the class, then they would recognize that the inclusion of alternative explanations in a response is evidence of collateral learning, and they would reward the conventional science explanations therein without penalty. Or, alternatively, these teachers of cross-cultural science curricula may decide to eliminate items in which there are requests for personalized explanations when contextualized stimuli are presented, and instead adopt a policy that students are cued explicitly for conventional science explanations. The findings of this study indicate the need for further research in this area.

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