Transcending Cultural Borders: Implications for Science Teaching

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Abstract

The current development towards “science for all” in all parts of the globe necessitates that consideration be given to how pupils move between their everyday life-world and the world of school science, how pupils deal with cognitive conflicts between those two worlds, and what this means for effective teaching of science. This paper reviews a new cognitive explanation — collateral learning theory — for how pupils cope with disparate worldviews mediated by transcending cultural borders between their everyday culture and the culture of science. The assistance that most pupils receive when they attempt to negotiate these cultural borders will influence their success at science. A new pedagogy is proposed in which teachers assume a role of culture broker in the classroom to achieve culturally sensitive curriculum and assessment.

Perhaps spurred on by reform efforts such as the National Curriculum in the UK, the National Research Council's Standards and AAAS's Project 2061 in the USA, or UNESCO's Project 2000+, science educators have reopened a global discussion about new directions in science education (KEDI, 1997). Many nations are currently rethinking their needs and priorities for school science in terms of “science for all.” Some reformers have targeted conceptual change as a focus for education change. However, the limited success of the conceptual change movement, according to McTaggart (1991), is due to its narrow superficiality grounded on psychological constructs. Others suggest that contemporary work on conceptual change instruction should be grounded on a social constructivist pedagogy (Werstch & Toma, 1992).

Social constructivism characterises the nature of knowledge to include the following: (1) knowledge is not a passive commodity to be transferred from a teacher to learners, (2) pupils cannot and should not be made to absorb knowledge in a spongy fashion, (3) knowledge cannot exist separate from the knower, (4) learning is a social process mediated by the learner’s environment, and (5) the prior or indigenous knowledge of the learner is of significance in accomplishing the construction of meaning in a new situation. All learning is mediated by culture and takes place in a social context. The role of the social context is to scaffold the learner, and provide hints and help that foster co-construction of knowledge while interacting with other members of the society (Linn & Burbules, 1993). Contemporary literature has shown that recognising the social context of learning, as well as the effect of the learner’s socio-cultural background in the teaching and learning of science, is of primary importance if a strong basic foundation is to be established for successful pupil achievement and affect outcomes (Cobern, 1994; Driver, 1979; Jegede, 1995; Ogawa, 1986; Ogunniyi, 1988; Solomon, 1989). Indeed, the call appears now to be for culture sensitive science education which probes what actually occurs in the minds and hearts of learners when they are being taught science (Hewson, 1988; Solomon, 1987). This is particularly relevant in the present circumstance in which the science education community seems to be travelling toward two destinations: understanding concept learning, and developing science-for-all programs.

In this article, we argue that these two destinations can be achieved simultaneously by giving attention to (1) the cross cultural experiences of most pupils when they attempt to construct scientific knowledge, and (2) a cognitive explanation (collateral learning theory) of that experience. These two ideas are presented and then synthesised in the context of teaching science. Implications for teaching will describe new teaching roles, strategies, and curricula.

A Multicultural Perspective

As we negotiate through the maze of daily interactions, we come across a mesh of different cultures or sub-cultures (Cobern, 1993; Jegede, 1995; Medvitz, 1996). For instance, a pupil encounters the culture of home, the culture of peers, the culture of school, the culture of the science classroom, and the over arching culture determined by the community in which the pupil lives. The concept of 'culture' is a shared way of living which includes knowing, valuing, interaction with others, feeling, etc. (Geertz, 1993). These characteristics of culture help explain the differences between a pupil's home culture and the culture of school science. The characteristics also differentiate between the various social groupings within the community: sub-cultures of the dominant genres of cultures. Whenever pupils enter the world of school science, it soon becomes evident that science too, is another culture with which s/he has to interact, bringing with him/her the other baggage of cultures s/he already carries. It does not take too long for the pupil to recognise that the science being taught at school has been influenced by the culture of the scientific community itself.

In an anthropological study, Traweek (1992) described the culture of a high-energy physics community:

> A community is a group of people with a shared past, with ways of recognizing and displaying their differences from other groups, and expectations for a shared future. Their culture is the ways, the strategies they recognize and use and invent for making sense, from common sense to disputes, from teaching to learning, it is also their ways of making things and making use of them ... . (pp. 437-438, italics in the original)

Traweek uncovered some coping behaviours by Japanese physicists as they negotiated transitions between the sub-culture of their Japanese national physics community and the sub-culture of the international physics community. She found that risks, power, and subjectivity were all intermingled in ways that encouraged conformity with the national physics community, and therefore made border crossing into the international community difficult for the Japanese physicists.

Consistent with both Geertz's (1973) and Traweek's (1992) ideas of culture, Phelan, Davidson and Cao (1991, p. 228) suggested that culture be conceptualised as the "norms, values, beliefs, expectations, and conventional actions" of a group. This cogent definition will guide our exploration of cultural border crossing and collateral learning in science education. Canonical science content will be subsumed under "beliefs." (For an overview of other definitions of culture used in science education, see Aikenhead, 1996, p. 8).

From the viewpoint of cultural anthropology, to learn science is to acquire the culture of science (Maddock, 1981; Wolcott, 1991). To acquire the culture of science, pupils must travel from their everyday life-world to the world of science found in their science classroom. More often than not, and more pervasive within local cultures in less industrialised or non-western regions of the world, the imported science curriculum or indeed the western science taught at school is often shown to be more superior to knowledge within the local culture. According to Taylor and Cobern (1998):

> local cultures are in danger of suffering erosion and loss of integrity as a powerful culture-insensitive science education, operating through the agency of local schools, delegitimates and rapidly displaces traditional ways of knowing, being and valuing.

Needless to say, this exerts a significant effect on achievement in schoolwork (Jegede, 1988; Jegede & Okebukola, 1989; Okebukola & Jegede, 1990), and in other cognitive activities (Glaser, 1991). Ogbu (1992) states that school learning and performance are influenced by complex social, economic, historical, and cultural factors. As a result, the less than friendly clash of cultures within the science classroom might lead to the loss of meaningful learning of science necessary for useful application in understanding nature outside of the school. The learning of what is therefore central to science education is inevitably lost within a system which legitimises the so-called superiority of the imported culture over the life-world experiences of the learner.

Different cultural processes are involved in the acquisition of science culture. When the culture of science generally harmonises with a pupil's life-world culture, science instruction will tend to support the pupils' view of the world, and the process of enculturation tends to occur

(Contreras and Lee, 1990; Hawkins and Pea, 1987; Wolcott, 1991). This process is characterised by smooth border crossings into school science.

However, when the culture of science is generally at odds with a pupil's life-world, science instruction will tend to disrupt the pupil's worldview by trying to force that pupil to abandon or marginalise his or her life-world concepts and reconstruct in their place new (scientific) ways of conceptualizing. This process is assimilation. Assimilation can alienate pupils from their Indigenous life-world culture, thereby causing various social disruptions (Baker and Taylor, 1995; Maddock, 1981); or alternatively, attempts at assimilation can alienate pupils from science, thereby causing them to develop clever ways (school games) to pass their science courses without learning the content in a meaningfully way assumed by the school and community.

The game can have explicit rules which Larson (1995) discovered as "Fatima's rules," named after an articulate pupil in a high school chemistry class. For example, one rule advises us not to read the textbook but to memorise the bold faced words and phrases. Fatima's rules can include such coping or passive-resistance mechanisms as "silence, accommodation, ingratiation, evasiveness, and manipulation" (Atwater, 1996, p. 823). What results is not meaningful learning but merely "communicative competence" (Kelly and Green, in press) or "an accouterment to specific rituals and practices of the science classroom" (Medvitz, 1996, p. 5). Loughran and Derry (1997) investigated pupils reactions to a science teachers' concerted effort to teach for meaningful learning ("deep understanding"). The researchers found a reason for Fatima's rules that helps explain the avoidance of assimilation for some pupils, a reason related to the culture of public schools.

> The need to develop a deep understanding of the subject may not have been viewed by them [the pupils] as being particularly important as progression through the schooling system could be achieved without it. In this case such a view appears to have been very well reinforced by Year 9. This is not to suggest that these students were poor learners, but rather that they had learnt how to learn sufficiently well to succeed in school without expending excessive time or effort. (p. 935)

Their teacher lamented, "No matter how well I think I teach a topic, the students only seem to learn what they need to pass the test, then, after the test, they forget it all anyway" (p. 925). On the other hand, Tobin and McRobbie (1997, p. 366) documented a teacher's complicity in Fatima's rules: "There was a close fit between the goals of Mr. Jacobs and those of the students and satisfaction with the emphasis on memorisation of facts and procedures to obtain the correct answers needed for success on tests and examinations." When playing Fatima's rules, pupils (and some teachers) go through the motions to make it appear as if meaningful learning has occurred, but at best rote memorization of key terms and processes is only achieved temporarily.

For a large majority of pupils, science teaching is experienced as an attempt to assimilate them (Costa, 1995; Ogawa, 1995). A vast array of science education research into pupils' construction of scientific concepts concludes that most pupils exhibit creativity and intransigence in their quest to circumvent the construction of scientific concepts (Driver et al., 1994; Loughran and Derry, 1977; Pfundt and Duit, 1994; West and Pines, 1985), that is, to circumvent assimilation and at the same time, avoid expending unnecessary effort.

When pupils learn science within a multicultural environment (inclusive of science being treated as a subculture of Western environment) they need to move between their everyday life-world and the world of school science. For a small proportion of pupils, crossing these cultural borders does not present problems serious enough to affect their learning of science. But many do experience serious problems and must deal with cognitive conflicts between those two worlds. According to Aikenhead and Jegede (1998, in press), this conflict is played out daily in science classrooms around the world where science pupils are expected to construct scientific concepts meaningfully; for example, in Africa where pupils' traditional cosmologies (Jegede and Okebukola, 1991) conflict with the norms, values, beliefs, expectations and conventional actions of the Western science community; in Canada where First Nations pupils' Indigenous culture tends to be at odds with the culture of Western science (Aikenhead, 1997); and in the United States where mainstream Euro-American pupils with aesthetic or religious orientations toward nature reject the worldview of Western science and choose not to learn it in any meaningful way (Cobern, 1996).

These cultural clashes between pupils' life-worlds and the world of Western science can create hazards for many pupils who they must deal with to learn science effectively and meaningfully. In response to such hazards, pupils understandably invent ways to avoid constructing scientific ("foreign") knowledge, or pupils conveniently store the constructed scientific knowledge in their minds out of harms way from interfering with their life-world experiences. The cultural clashes between pupils' life-worlds and the world of Western science present a challenge to science educators. These clashes create a major obstacle to many reform movements around the world that have taken on a science-for-all ideology. Specifically it makes science teaching a Herculean task and the meaningful learning of science an ordeal for many pupils. The ideas of cultural border crossing and collateral learning can inform this worldwide discussion by offering new insights into the resolution of familiar problems related to the teaching and learning of science.

Cultural Border Crossings

The idea of cultural border crossing emerged from Giroux's 1992 book <u>Border Crossings: Cultural Workers and the Politics of Education</u>. In it he contrasts modernist and postmodernist views on education. On the one hand, modernism defines borders and locates people within those borders along with the social and political power afforded each location. On the other hand, postmodernism encourages people to have multiple identities by living in a world of border crossings, and living with multiple narratives that define reality (p. 54), for example, narratives that sustain a pupil's home culture and narratives that allow for his or her participation in the world of science.

In a detailed self study of border crossing, Lugones (1987) revealed a personal account of "travelling" from her own world of a woman of colour to the often hostile world of the White Anglo male. Her account echoes the multiple narratives of many pupils when they cross hazardous borders from their familiar life-world cultures into the unfamiliar culture of school science. Lugones became accomplished in the Anglo male's world without losing her own way of thinking, because she learned to cross hazardous borders effectively. Her experiences suggested the following ingredients for successful border crossing: a sense of flexibility, playfulness, and/or feelings of ease. These ingredients help clarify the human capacity to think differently in different cultures, a capacity that has implications for pupils’ success at learning science.

In the context of teaching science for all, Aikenhead and Jegede (1998) described the act of cultural border crossing into school science and its cognitive explanation (collateral learning). They drew upon cultural anthropology which regards the learning of science as the acquisition of the culture of science. They opine that to acquire the culture of science, pupils must travel from their everyday life-world to the world of science found in their science classroom. A brief summary of this border crossing is presented here.

The capacity to think differently in diverse cultures (everyday and science cultures, for instance), and the capacity to resolve conflicting beliefs between those cultures, are familiar human traits. However, these capacities are not equally shared among all people, as anthropologists Phelan et al. (1991) discovered when they investigated pupils’ movement between the worlds (sub-cultures) of families, peer groups, school, and classrooms:

> Many adolescents are left to navigate transitions without direct assistance from persons in any of their contexts, most notably the school. Further, young people’s success in managing these transitions varies widely. (p. 224)

Costa (1995) studied pupils’ varied success at moving between the sub-culture of their family and the sub-culture of their science classroom. She confirmed Phelan et al.’s findings and proposed a categorisation scheme that described pupils in terms of their ease of navigating the cultural border into school science. Four categories of pupils are:

1. <u>Potent Scientists</u> whose transitions are <u>smooth</u> because the cultures of family and science are congruent;
2. <u>Other Smart Kids</u> whose transitions are <u>manageable</u> because the two cultures are somewhat different;
3. <u>“I Don't Know” Students</u> whose transitions tend to be <u>hazardous</u> when the two cultures are diverse; and
4. <u>Outsiders</u> whose transitions are virtually <u>impossible</u> because the cultures are highly discordant.

This categorisation scheme will be used extensively throughout this article.

One overwhelming conclusion emerges from educational research in cultural anthropology (Aikenhead & Jegede, 1998): success in science courses depends on (1) the degree of cultural difference that pupils perceive between their life-world and their science classroom, (2) how effectively pupils move between their life-world culture and the culture of science or school science, and (3) the assistance pupils receive in making those transitions easier.

Border Crossings

A concept that describes the high risk of failure during cultural border crossing is “cultural violence,” the explicit version of Bourdieu's (1992) tacit “symbolic violence.” When language or conventional actions of a group have little or no meaning to a person who happens to be immersed in that group and who needs to accomplish some action, the person can experience cultural violence. In the context of a world traveller, a Chicago businessperson, for instance, may experience cultural violence at a Tokyo hotel when he or she needs to take a shower and discovers that the only place is the public bath located on the tenth floor. Public bathing, a conventional action in Japanese culture, may cause cultural violence to any traveller who harbours a psychological need for privacy when bathing. The cultural symbol of the public bath causes anguish to the Chicago traveller due to the dilemma between the need to bathe and the high risk of mental discomfort. For the traveller experiencing cultural violence, border crossing becomes hazardous at best (somehow one copes), or impossible at worst (one does not take a bath).

In the context of life in the Solomon Islands, border crossing between urban and rural settings caused anguish for some high school pupils but not others. Science pupils in the main city of Honiara talked about going to rural villages and encountering the idioms and technologies of magic endemic to the Indigenous culture of the Solomon Islands (Lowe, 1995). For pupils who grew up in a village, the transition back into rural life was automatic, natural, and smooth. But for pupils born and raised in Honiara, the cultural border crossing was difficult and hazardous. These pupils reacted to practices of magic as forms of symbolic violence.

In the context of pupils learning science, O’Loughlin (1992), Tobin (1996) and Lee (1997b) argue that the language and conventional actions of many Euro-American teachers in science classrooms may be experienced as cultural violence by pupils belonging to a culture different from the teacher's culture. In non-Western countries, the science curriculum itself may be experienced as cultural violence by pupils who strongly believe in their community's Indigenous belief system, whether it be anthropomorphic Africa (Jegede, 1995) or Solomon Island magic (Lowe, 1995). Science education worldwide aims to eradicate cultural violence and to nurture equitable opportunities for success for all pupils (UNESCO, 1994). Because success at science depends in large measure on how effectively pupils can move between their life-world culture and the culture of science, it is imperative to understand how these border crossings take place in order to plan and develop effective and sensitive instruction

Collateral Learning

Effective cultural border crossing is indeed a complex event. The <u>cognitive</u> experience of border crossing is captured by the theory of collateral learning (Jegede, 1995). The phenomenon to which collateral learning refers is universal and well known worldwide and the theory was proposed to explain why many pupils, non-Western and Western, experienced culturally related cognitive dissonance in their science classes (Jegede, 1995).

Collateral learning generally involves two or more conflicting schemata held simultaneously in long-term memory. Jegede (1995, 1996, 1997) recognised variations in the degree to which the conflicting ideas interact with each other and the degree to which conflicts are resolved. Collateral learning theory postulates a spectrum of cognitive experiences (parallel, simultaneous, dependent, and secured collateral learning) to explain cultural border crossings These four types of collateral learning are not separate categories but points along a spectrum depicting degrees of interaction/resolution.

At one extreme of collateral learning, the conflicting schemata do not interact at all. This is <u>parallel</u> collateral learning, the compartmentalization technique. Pupils will access one schema or the other depending upon the context. For example, pupils will use a scientific concept of energy only in school, never in their everyday world where commonsense concepts of energy prevail (Solomon, 1983). This segregation of school science content within the minds of pupils was called "cognitive apartheid" by Cobern (1996).

At the opposite extreme of collateral learning, conflicting schemata consciously interact and the conflict is resolved in some manner. This is secured collateral learning. The person will have developed a satisfactory reason for holding on to both schemata even though the schemata may appear to conflict, or else the person will have achieved a convergence toward commonality by one schema reinforcing the other, resulting in a new conception in long-term memory. Various ways to resolve conflicts and to achieve secured collateral learning are described in the next section of this article.

Between these two extremes of parallel and secured collateral learning we find varying degrees and types of interaction between conflicting schemata, and we detect various forms of conflict resolution. In this context it will be convenient to designate points in between the two extremes, one of which is called dependent collateral learning. For many pupils, learning science in order to imbibe its culture meaningfully often involves cognitive conflicts of some kind. Therefore, meaningful learning often results in parallel, dependent, or secured collateral learning. For a learner who needs to move into the culture of science, s/he requires an effective use of collateral learning with a heavy reliance on successful cultural border crossings into school science.

Cross-Cultural Science Education

In many different cultural settings educators have anguished over teaching Western science without assimilating pupils at the expense of diminishing pupils' cultural identities (Baker and Taylor, 1995; Hodson, 1993; Jegede, 1995; Kawagley, 1995; Lee, 1997b; Lowe, 1995; MacIvor, 1995; Nelson-Barber and Estrin, 1995; Ogbu, 1992; O'Loughlin, 1992; Philips, 1972; Pomeroy, 1994). Kaunda (1966) in Africa, for example, voiced the dilemma in terms of preserving what is good in pupils' personal cultural tradition while at the same time allowing them to benefit from Western science and technology. His position occupies the middle ground between two extremes: the total assimilation into Western science, and the rejection of Western science.

Science educators have developed innovative programs, new curriculum, and creative instruction to help pupils. By engendering a feeling of ease in the culture of science, educators have tried to encourage pupils to cross cultural borders into school science. Pomeroy (1994) reviewed this literature and found nine different (and overlapping) research agendas. Her work frames several decades of research and development in multicultural and cross-cultural science education. The nine agendas are listed here along with some major research findings.

1. Systems or Programs to Support Under-Represented Groups: Role models are less effective than mentors. A critical mass of “minority” scientists is highly effective, but how to best achieve a critical mass remains debatable. No long-term or exemplary programs have been identified.
2. Situate the Science Curriculum in the Context of Pupils' Lives: Research is only beginning to focus on local autonomy for curriculum development and pupil assessment. Examples of a relevant localised context for science instruction can be cited, but their impact has not been systematically studied.
3. Culturally Sensitive Instruction Strategies: Research has focussed on identifying the problems that exist (discrepancies between pupils and their science classes in terms of interpersonal mores, conventions and expectations, such as eye contact, questioning, authoritarianism, etc.) and focussed on theoretical frameworks that should address the problem. Teachers' high expectations of pupils appear to improve achievement.
4. Inclusion of Scientific Contributions made Historically by Non-Western Scholars. Western science has appropriated knowledge of nature from other cultures, thus giving the impression that other cultures have not helped in the historical development of Western science. Systematic studies have not yet assessed this initiative.
5. Demystifying Stereotype Images of Science: Stereotype images of science (e.g. science is purely objective and value-free) inhibit many pupils from wanting to learn science. The “nature of science” literature is extensive with systematic studies offering an array of implications for teaching science.
6. Science for Language Minority Pupils: Learning science in a language not in one's mother tongue, creates major problems for one's achievement. Mother tongue instruction is the best solution.
7. Indigenous Knowledge and Technologies for Science to Explain: By addressing pupils' cultural heritage as objects of scientific inquiry or explanation, pupils' attitude toward

science tends to improve. For instance, by simply acknowledging omens and taboos (without discussing them in terms of scientific principles) in science classrooms, pupils tend to transcend cultural barriers (to cross borders) between their Indigenous culture and the culture of science. The instructional outcome will likely be dependent collateral learning, it could be parallel collateral learning if the “truth-will-out-device” (Roth and Alexander, 1997) were used.

8. Compare and Bridge the Worldview of Science and the Worldviews of Pupils. Pupils' scientific preconceptions (the object of constructivist teachings) can be perfectly logical when considered in terms of a pupil's worldview, and therefore, efforts to modify the preconception will be ineffective. Effective teaching tends to use science activities that do not conflict with pupils' beliefs, or alternatively, activities that attend to those beliefs but provide bridges between them and the scientific content. The instructional outcome will likely be parallel or simultaneous collateral learning.
9. Explore the Content and Epistemology of Both Scientific and Indigenous Knowledge Systems: The exploration encourages pupils to identify any conflicts between the two systems and to feel secure with those conflicts. The impact on pupils has not yet been studied extensively. The instructional outcome will usually be secured collateral learning.

Agendas 1 to 6 tend to assimilate pupils into Western science, whereas agendas 7 to 9 challenge us to conceive of alternatives to assimilation (and to Fatima's rules); a challenge clarified by the concepts of cultural bordering crossing and collateral learning.

Implications for Science Teaching

Cultural differences between a pupil and school science inspired a cross-culture pedagogical paradigm for teaching science — a conceptual ecocultural paradigm: “a state in which the growth and development of an individual's perception of knowledge is drawn from the sociocultural environment in which the learner lives and operates” (Jegede, 1995, p. 124). This approach to teaching science was recommended by Jegede primarily for Africans, by Arseculeratne (1997) for Sri Lankans, by Nelson-Barber and Estrin (1995) for Native Americans, by Pomeroy (1992) for Native Alaskans, by Ogawa (1995) for Japanese pupils, by

George and Glasgow (1988) for Caribbeans, by Solomon (1992) for all pupils, and by Aikenhead (1996) for Western pupils who are not Potential Scientists (using Costa's [1995] category scheme). Teaching science within an ecocultural paradigm aims to empower pupils to feel at ease (in the Lugones [1987] sense of ease) in each culture, for instance, the culture of science and the pupil's Indigenous life-world cultures. According to Jegede (1995), a conceptual ecocultural paradigm consists of the following features:

1. generating information about the pupil's everyday environment to explain natural phenomena.
2. identifying and using the Indigenous scientific and technological principles, theories, and concepts within the pupil's community.
3. teaching the typical values of the Indigenous community in relation to, and in the practice of, science and technology as human enterprises.

Because all three features relate to Lugones' (1987) criteria for feeling at ease in a “foreign” culture, the features should help pupils negotiate their cultural borders into school science. In short, the ecocultural paradigm acknowledges cultural differences, provides emotional support for pupils, and sets the stage for cross-cultural instruction.

Because success in science courses depends on how effectively pupils move between their life-world culture and the culture of science, other implications for teaching science (complementary to, and overlapping with, Jegede's ecocultural paradigm) have been proposed (Aikenhead, 1996, 1997b; Cobern and Aikenhead, 1997):

1. Make border crossings explicit for pupils.
2. Facilitate these border crossings.
3. Promote discourse so pupils are: (a) talking in their own cultural interpretive framework as well as in the framework of Western science without cultural violence, (b) immersed in either the pupils' Indigenous life-world culture or the culture of science, and (c) cognizant about which culture they are talking in at any given time.
4. Substantiate and build on the validity of pupils' personally and culturally constructed ways of knowing.

5. Teach the canonical content of Western science and technology in the context of science's societal roles, for instance, science's social, political, military, colonial, and economic roles.

These implications strengthen agenda 9 in Pomeroy's (1994) cross-culture research agendas, but they may not be comfortable for pupils with a holistic outlook on knowledge (described in Aikenhead & Jegede, 1998), and they may seem foreign to many Potential Scientists who desire enculturation into science.

The promotion of discourse among pupils was the object of extensive study by Roth (1997). He argued that the social construction of scientific knowledge required “interpretive flexibility,” a multiple-world approach to understanding the existence of multiple views among people (particularly within the scientific community). Interpretive flexibility allowed pupils “to change from their everyday discourse to that of canonical science” (p. 392). Roth concluded: “We found that such changes in discourse were facilitated when pupils had the opportunity to work and talk together, but in the absence of a perceived authority which often inhibits their first attempts in trying out a new discourse” (p. 392). On the other hand, Driver et al. (1994) argued that pupils’ discourse in science can be facilitated by a teacher who introduces vocabulary and syntax at appropriate places during a pupil-centred discussion. Much more research along these lines is needed to understand the function of pupil discourse in meaningful learning.

Although the five implications listed above were originally proposed for most Western pupils (non-Potential Scientists) studying in technologically developed countries, the implications also correspond to curriculum proposals for pupils in developing countries (Jegede, 1997; Lowe, 1995; Medvitz, 1985; Yoong, 1986), as well as for pupils traditionally marginalised from science in Western industrialised countries (Atwater, 1996; Lee, 1997b).

Teacher as Culture Broker

Success in science courses depends on teachers helping pupils mediate or negotiate cultural borders and engage in some form of collateral learning. The metaphor “teacher as culture broker” was used by Stairs (1995) to analyse a teacher's role in resolving cultural conflicts that arise in cross-cultural education. A science teacher who is a culture broker will guide pupils between their life-world culture and the culture of science, and help them resolve any conflicts. Atwater (1996) described this role as a coordinator, facilitator, and resource person in multicultural education, while in a sociological paradigm, Kelly and Green (in press) talked about a “social mediator.”

For pupils who require a high degree of guidance when border crossing, just like <u>tourists</u> in a foreign country on a guided bus tour, teachers will be <u>tour-guide</u> culture brokers. Drawing upon Costa's (1995) scheme, we would describe their pupils as predominantly “I Don't Know” Students, and perhaps Outsiders who are amenable to becoming “I Don't Know” Students within a supportive ecocultural paradigm and with an effective culture-broker teacher. A tour-guide culture broker takes pupils to some of the principal sites in the culture of science (its significant phenomena, knowledge, skills, and values) and coaches pupils on what to look for and how to use it in their everyday lives outside of school. A tour guide helps smooth the otherwise hazardous or impossible border crossings that pupils face. A tour-guide teacher often expects that a science course will develop an appreciation of science, not unlike a music appreciation course that aims to guide pupils through the world of music and its critique, without requiring them to compose music or exhibit virtuosity with an instrument. The role of tour guide does not imply didactic teaching methods; a much wider repertoire of methods is needed (Aikenhead, 1996).

For pupils who require much less guidance when border crossing, just like world <u>travellers</u> in a foreign country making their own way around, teachers will be <u>travel-agent</u> culture brokers. Their pupils will be predominantly Other Smart Kids, also learning within an ecocultural paradigm. A travel-agent teacher provides incentives for pupils, such as topics, issues, activities, or events that create the need to know the culture of science. The need to know establishes an academic bridge between pupils' life-worlds and the culture of science. These academic bridges represent less guidance than most “I Don't Know” Students need. Academic bridges help Other Smart Kids manage their border crossings into the culture of science. The bridges assist pupils in constructing key scientific abstractions (e.g. DNA) and assist them to be articulate in analysing or critiquing the culture of science itself. Pupils will likely perceive the sub-culture of science as interacting with other sub-cultures that form a fairly coherent unity in their lives. The teacher's travel-agent role is one of co-learner facilitating issue-directed learning (Ritchie, 1994).

A detailed comparison between tour-guide and travel-agent roles for culture-broker science teachers is illustrated in Aikenhead (1996). The difference between the two roles is a matter of <u>degrees of</u> guidance and pupil intellectual maturity, rather than different kinds of guidance or differently types of intellectual maturity. The two roles are not dichotomous. In either role, a teacher makes the culture of science accessible to pupils by methods predicated on cross-cultural instruction (Atwater, 1996; Pomeroy, 1994) and guided by Lugones' (1987) flexibility, playfulness, and feelings of ease.

Ogawa's (1995) "multiscience" instruction supports a culture-broker role, as does Nelson-Barber and Estrin's (1995, p. 24) view of science education for Native American pupils: "The task for teachers ... becomes one of helping students mediate between their personal meanings, their own culture-based systems, and the systems of school." Culture broker is a fairly new idea, but one that can make intuitive sense to teachers. We all can imagine how we would introduce a foreigner into our own culture, under the constraints of formal schooling. The idea of culture broker has potential for helping teachers hone their existing teaching strategies, or reformulate and develop additional strategies, to harmonise with their classroom sub-culture and personal practical knowledge.

Interactive Teaching Strategies

Many specific teaching strategies for culture brokers have yet to be identified, developed, or investigated (Atwater, 1996; Battiste and Barman, 1995; Jegede, 1997; Lee, 1997b; Lee et al., 1995; Pomeroy, 1994; Snively, 1995). However, some research has taken place by people exploring the consequences of introducing interactive teaching strategies that relate school content with the pupils' everyday world. (Interactivity among pupils and content relevancy for pupils' lives are two criteria that seem to make the biggest difference to pupils' meaningful achievement in science, Aikenhead, 1994.) In Nepal, for example, a researcher introduced a strategy he called "a narrative approach" (Bajracharya and Brouwer, 1997). It was one way to create a bridge between Nepalese and Western science cultures and to facilitate border crossings between the two. The narrative approach involved small group discussions on questions as:

“Crows don't die a natural death, do they?” (p. 436). This was Bajracharya and Brouwer's way of establishing, in small measure, a conceptual ecocultural paradigm in which Bajracharya and three volunteer teachers began to play the role of culture broker for their pupils. It is also an example of Pomeroy's (1994) agendas 7 and 8. The cultural obstacles that needed to be overcome in the Nepalese schools were also investigated by the researchers. Teaching strategies are neither culture-free nor ideologically neutral (Aikenhead, 1997a), and therefore, researchers need to be sensitive to the cultural milieu where innovations are tested.

Another example of a strategy for culture broking in a science classroom comes from Canada, where border crossing was made concrete for pupils by a line that divided a notebook page in half forming two columns: “my ideas” and “culture of science ideas” (Aikenhead, 1996). After exploring phenomena or discussing explanations, pupils made personal notes by writing either in the “my ideas” column or in the “culture of science ideas” column, or both. Entries in the science column signified a pupil's understanding of the content, not necessarily a pupil's belief that the content is universally true (Cobern, 1996a; Ogunniyi, 1988). The dichotomised notebook page served as a type of journal which helped guide pupils' thinking and their use of language, just as a culture tour guide or travel agent would. It was up to the teacher to assess the quality of the pupils' entries in both columns; both had a place in the assessment.

When moving back and forth over the line dividing the notebook page, a pupil consciously moves back and forth between the everyday world (the pupil's cultural identity) and the science world (the culture of science): switching terminology explicitly, switching language frameworks and conventions explicitly, switching conceptualizations explicitly, switching ontological assumptions explicitly, switching epistemologies explicitly, and switching values explicitly. This is the essence of thinking differently in two different cultures. The notebook technique by itself will not ensure smoother border crossings for pupils, but it may help a teacher develop his or her own repertoire of cross-cultural teaching strategies.

Encouraging is Solomon's (1992) success with some pupils’ learning energy concepts. She described how teachers explicitly coached pupils to move between their life-world and the science-world, accentuating flexibility, playfulness, and feelings of ease. Snively (1995) delineated 15 specific instructional strategies and considerations for culture brokers to use when teaching Western science to First Nations pupils. These are summarised here:

1. Use a variety of materials and resources, and ensure that racially stereotyped material is either eliminated or addressed in an anti-racist fashion.
2. “The oral narratives and heritage of the Native community should become part of the school science experience” (p. 65). These should not be demeaned as being merely myth and legend.
3. “The similarities and differences and the strengths and limitations of the two traditions should be articulated and explored during instruction” (p. 66).
4. Teachers should give attention to the language of science and help pupils who are accustomed to an oral tradition or who have language difficulties.
5. “Cultural imperialism should be acknowledged” (p. 66).
6. Integrate discussions about science with history, morality, justice, equality, freedom, and spirituality.
7. Where possible, direct comparisons between classification schemes in both traditions should be made.
8. Show pupils how concepts such as heat, snow, and life cycles are culture-laden in both traditions.
9. Instruction should provide sensory experiences and experiential pupil-centred learning.
10. “Instruction should identify local approaches for achieving sustainability” (p. 66).
11. The pupil's world should be related to science instruction.
12. Teachers should provide a “multicultural view” of science and technology by drawing upon a variety of cultures when teaching science.
13. “Activities should be designed to help students recognize the likelihood of continual change, conflict, ambiguity, and increasing interdependence” (p. 66).
14. Interactivity among pupils should encourage them to identify their own ideas and beliefs.
15. “Teaching strategies should emphasize solving science and technology problems, environmental problems, resource management, and sustainable societies' problems” (p. 67). Pupil empowerment is the goal.

Snively's ideas, grounded in research and experience, offer practical advice and extend our vision of a new pedagogy for cross-culture science teaching.

We have already recognised the negative consequences to attempts by conventional science instruction to enculturate and/or assimilate pupils into science. We subscribe to the belief that enculturation for Potential Scientists (a very small proportion of the pupil population) is in many cases desirable. Our “no assimilation” rule would not preclude us from capturing pupil interest or curiosity in science and then doing a good job at a rite-of-passage enculturation into the culture of science (Costa, 1993; Hawkins and Pea, 1987). Because the process of enculturation — producing scientists and engineers — has preoccupied the science education community (Aikenhead, 1996; Contreras and Lee, 1990; Costa, 1993; Driver et al., 1994; Hawkins and Pea, 1987; Pomeroy, 1994), the process of enculturation is given low priority in this article, except in our exploration of collateral learning. Instead we privilege Other Smart Kids, “I Don't Know” Students, and Outsiders, in all cultures; pupils who conventionally have been the target of assimilation processes because their border crossings into school science have not been smooth. Attempts to assimilate may work for Potential Scientists, but the attempts lead most other pupils to Fatima's rules. What are the alternatives to enculturation and assimilation? Two alternatives exist. The first one is acculturation, a process of intercultural borrowing or adaptation in which a person incorporates attractive content or aspects of another culture into the person's own culture (Spindler, 1987). To emphasise the empowerment of pupils and the usefulness of the incorporated content, Aikenhead (1997b) used the term “autonomous acculturation” in which:

> a pupil borrows or adapts (incorporates) some content from Western science and technology because the content appears useful to him/her, thereby replacing some former indigenous views. Everyday thinking is an integrated combination of commonsense thinking and some science/technology thinking. (p. 230)

Autonomous acculturation, associated with dependent collateral learning is demonstrated in a case study of Luke, an Aboriginal boy in grade 6 studying the seashore (Snively, 1990). Luke's teacher explicitly supported the culture of his First Nation, and she helped all her pupils negotiate impossible or hazardous borders into school science. As a successful culture broker, she was able to transform some Outsiders into “I Don't Know” Students, or even into Other Smart Kids. Other examples of autonomous acculturation are detailed in Aikenhead (1996). One feature of acculturation’s dependent collateral learning (for teachers to keep in mind) is the modification or replacement of pupil's pre-existing schemata, a modification motivated by how relevant the new schemata are to a pupil's cultural identity and life-world.

Autonomous acculturation is not the only alternative to enculturation and assimilation. Pupils need not modify or relinquish pre-existing schemata before they understand science. In other words, pupils need not modify their cultural identity to understand and participate in some of the cultural ways of science (Ogunniyi, 1988). Instead, pupils might engage in parallel collateral learning by adding a science schema (one that conflicts with pre-existing schemata) to their long-term memory, and by compartmentalizing the science schema so no conflict is experienced (Cobern's cognitive apartheid mentioned earlier). These pupils likely learn the content of science in a way similar to an anthropologist learning a foreign culture (Medvitz, 1985, 1996). The culture of science is understood by pupils (just as anthropologists understand another culture), but scientific thinking does not guide their everyday thinking; yet these pupils can do either type of thinking, depending on the context. Thus, a different cultural process can be identified to guide science teaching strategies, a process Aikenhead (1996, p. 34) called “'anthropological' instruction of science.” Pupils are placed in a position similar to that of an anthropologist. “Anthropological” instruction/learning recognises that many preconceptions are highly useful to pupils in certain contexts (Hill, 1989; Kwon, 1997). Hence, when pupils learn scientific explanations, they learn to contextualise those explanations as belonging to a “tribe” of scientists, and at the same time, pupils are invited to use their preconceptions in appropriate everyday contexts (but not science contexts). In other words, pupils are invited to use the “my ideas” column or the “culture of science ideas” column in their notebook, depending on the situation. This amounts to concept proliferation, rather than concept modification or replacement (Solomon, 1987) and has been the object of research in the situated cognition paradigm (Hennessy, 1993).

“Anthropological” instruction may seem too academic or too removed from the everyday world to nurture feelings of ease for “I Don't Know” Students and Outsiders. It may appeal only to Other Smart Kids, and perhaps to some Potential Scientists. “Anthropological” instruction addresses the needs of pupils who find border crossings to be manageable or smooth. The culture of science is treated as an intellectual game.

But the culture of science can also be treated as “a repository to be raided for what it can contribute to the achievement of practical ends” (Layton et al., 1993). For instance, the technological success of Japan in the 20th century was explained by Ogunniyi et al. (1995, p. 822): “The Japanese never lost their cultural identity when introducing Western science and technology, because they introduced only the practical products of Western science and technology, never its epistemology or worldviews.”

For many pupils worldwide, conventional school science seems highly disconnected from practical ends. “Science learned in schools is learned as science in school, not as science on the farm or in the health clinic or garage” (Medvitz, 1985, p. 15). This criticism is addressed by cross-cultural science instruction that promotes parallel, simultaneous, dependent, or secured collateral learning, which may be achieved through enculturation, “anthropological” instruction/learning, or autonomous acculturation. These cultural processes rely on the effectiveness of culture brokers, such as Luke’s science teacher, who make Western science accessible to all pupils in their everyday worlds by assisting them to negotiate cultural borders into school science. These pedagogical culture workers need to be brought into the research programs of cross-cultural science education. They have much to offer.

In summary some relationships among cultural border crossing, collateral learning, and implications for science teaching are summarised in Table 1. The anthropological research conducted by Phelan et al. (1991) established four types of border crossings that pupils experience when attending school (column 1 in Table 1). Costa (1995) confirmed these results specifically for science pupils and suggested at least four categories of pupils (column 2). The next two columns depict a cultural perspective on science education associated Costa’s categories by identifying three cultural processes endemic to meaningful and non-coercive learning (column 3) and by identifying three concomitant roles for science teachers to play (column 4). Collateral learning theory postulates a spectrum of cognitive experiences (parallel, simultaneous, dependent, and secured collateral learning) that helps explain cultural border crossings (column 5).

Table 1 fits here.

Curriculum and Assessment

Culture-broker science teachers will need a cross-cultural curriculum, a curriculum sensitive to the cultural identity of pupils (Jegede et al., 1996; Ogunniyi, 1988) and characterised by agendas 7, 8 and 9 in Pomeroy's (1994) review of multicultural and cross-cultural science education. Instead of bringing pupils into Western science and insisting they assume a scientist's perspective on nature and technology (the conventional enculturation or assimilation into science), a cross-cultural science curriculum appropriates knowledge, skills, and values from Western science and places them into a perspective that has scope and force (relevance) for pupils, that is, science for all. For instance, a unit of study or lesson could be introduced by recognizing a community's Indigenous knowledge or worldview in a way that creates a need to know Western science (Pomeroy's 7th agenda).

Alternatively, a unit of study or lesson might include Indigenous content along with Western science content to explore certain phenomena in depth (Pomeroy's 8th agenda). For example, First Nations traditional ecological knowledge (TEK) can be combined with various fields of Western science (ecology, botany, biology, medicine, and horticulture, to name a few) to give pupils an enriched understanding of nature in line with sustainable development (Corsiglia and Snively, 1995). Snively (1995) outlines a five-step process for producing a TEK unit in cross-cultural science teaching. For Western pupils who fit Costa's (1995) categories of Other Smart Kids and "I Don't Know" Students, Aikenhead (1996) provided details for critically analyzing both the students' Indigenous commonsense knowledge and the canonical content of Western science. Curriculum topics included mixtures, concentration, the logic of inference, and the manipulation of scientific data.

Exemplifying Pomeroy's 9th agenda, Aikenhead (1997b), Cajete (1994), Kawagley (1995), MacIvor (1995), and Nelson-Barber and Esterin (1995) proposed for First Nations pupils, and Jegede (1997) proposed for African pupils, cross-cultural STS curricula that combined Indigenous commonsense knowledge, Indigenous and Western technology, and Indigenous and Western knowledge of nature (science). Their “multiscience” approaches (Ogawa, 1995) included a reflection on the epistemology and ontological assumptions of Indigenous and Western science knowledge systems. These types of curriculum proposals should help teachers create an appropriate ecocultural paradigm for instruction. A TEK Western science curriculum could also be developed along these lines, as described by Corsiglia and Snively (1995). Curriculum development in cross-cultural science education is only in its infancy stage. Consequently, of the examples that exist, all come from local initiatives only. For example, Circles & Lines, is a grade 7 to 9 science curriculum for First Nations pupils in Ontario, Canada (Ahkwesahsne Mohawk Board of Education, 1994; Henderson, 1996).

The assessment of pupil achievement within the cross-cultural science curricula mentioned above has been mapped out by Nelson-Barber and colleagues (1996). They offer guidance and specific recommendations for developing a culturally responsive assessment system, beginning with “treat linguistic and cultural diversity as strengths” (p. 8). An example from the Navajo Nation demonstrated the fruitfulness of “portfolio assessment.” Portfolios were shown to promote pupil autonomy and reflected the context of learning, not just the process and product of learning.

Summary

Several years back, it would have been difficult if not impossible to dwell so much on the cultural aspects of science education as we have done in this article. Many who perhaps claim to be gate keepers of Western science would have rationalised their objection with arguments ranging from the rationality and objectivity of science (the so-called marked differences between the realm of science and the realm of culture) to the universality of science (a controversial issue in itself; Stanley and Brickhouse, 1995). Contemporary changes in science education, however, have given high priority to the goal “science for all,” for reasons which include equity, equality, and economic, political, and cultural realities of the modern world (UNESCO, 1994). For example, we live in a world of globalization which requires the demystification of science and the elimination of science’s exclusive preserve as a place for an elite select few (Fensham, 1992). The multicultural realities of many of the world's classrooms dictate that if any nation ignores the development of a science-for-all curriculum, it does so at its own peril (KEDI, 1997).

Whether in Africa, the South Pacific, Asia, and South America where Indigenous pupils form part of the predominant culture, or in other parts of the world such as Canada, the USA, Australia, and Europe, where the minority Indigenous populations are made to function within the dominant Western culture, science education is neither culturally appropriate nor culturally inclusive (Jegede et al., 1996). Even for pupils who come from the dominant Western culture, studying science can pose major cultural problems (Aikenhead, 1996; Costa, 1995). Worldwide, pupils are reacting to inappropriate and exclusive school science by voting with their feet. The exodus from science classes stares science teachers in their face everyday (KEDI, 1997).

It is evident from the literature that pupils experience at least two types of culture when they study science in a formal Western type educational setting: the culture of school science and the culture of their life-world. To make meaning out of their experiences in science classrooms, pupils need to negotiate a cultural transition from their life-world into the world of school science. The ease or difficulty with which pupils make the transition (that is, the ease or difficulty with which they cross cultural borders) will determine their understanding of the subject. The absence of psychological pain leads to a smooth border crossing. At the opposite extreme, the experience of unbearable psychological pain necessitates avoidance and leads to an impossible border crossing.

As emphasised throughout this article, cultural border crossing relates to pupils from both Indigenous and Western cultures. Life-world cultural knowledge (Shutz and Luckmann, 1973) acts as reliable prior information and as a framework through which further learning takes place. Life-world cultural knowledge affects the ease of cultural border crossing. When science culture is in harmony with a learner’s life-world knowledge, learning science concepts reinforces the pupils’ worldview suppositions. This, in turn, leads to enculturation (Contreras and Lee, 1990). Even for the pupils who cross cultural borders smoothly into science, however, certain factors (such as a lack of motivation, lack of interest, ineffective instructional strategies, inability to relate what is learned to the world of work) might make border crossing problematic and at odds with school science, as Champagne, Klopfer, and Anderson (1980) found in their study of pupils in Western societies.

Pupils in non-Western societies confront complications in addition to the factors which engender low interest in Western societies. At home, non-Western pupils function within a life-world knowledge system diametrically opposed to the knowledge, skills, attitudes, values, language, etc., taught in school science — content that bears characteristics of a Western orientation (Rashed, 1997). The eco-cultural environment of non-Western learners (Jegede, 1989, 1995) determines their social and cultural imprints of how knowledge is acquired and how it is used. At school, the science concepts taught as symbolic knowledge (Shutz and Luckmann, 1973) can become a source of “cultural violence” (the explicit form of Bourdieu's [1992] “symbolic violence,”) and non-empowerment (O’Loughlin, 1992), resulting in serious conflict between what pupils bring into the science classroom and what they are expected to take away from it. As a result, a large majority of pupils in non-Western societies cannot cross cultural borders smoothly into school science, and therefore, they do not learn science in the meaningful way expected of them. Instead they play some form of Fatima’s rules (Larson, 1995).

We recognise that some pupils (and they are in a very small minority) are able to smoothly negotiate the transition from their non-Western culture to the culture of science. According to Medvitz (1985), these pupils felt comfortable in each world but found themselves thinking differently in each setting. In relation to our thesis of cultural border crossing and collateral learning theory, where smooth and effortless transitions should result in a good fit between one cultural idea and the other, one can still question the acceptability of what these people experience as smooth cultural border crossings. It may well be that the attainment of secured collateral learning is being stunted.

Science education must be culture-sensitive for it to serve the emerging global community, the norm in the next millennium. Taylor and Cobern (1998) have proposed a new perspective for science education reform called “critical enculturation” which takes a dynamic view of culture, involves a dialectical view of the process of cultural adaptation, and which must recognise the need for reciprocal accommodation of the beliefs, values and practices of modern science and the host culture. It is only through this process of mutual respect of cultures within a multicultural environment that education for scientific culture can flourish. In this article, we have provided a modest start towards identifying the teaching and learning of science from this new perspective, in which learners attempt to transcend the borders of the culture of science and the culture of the learner’s environment. Curriculum and instruction must make science more accessible to all pupils, no matter the differences with their immediate culture. Indeed, these differences as demonstrated in this article could be harnessed to provide rich, robust and holistic experiences for the learner in a multi-faceted world.

References

AAAS. (1989). Project 2061: Science for all Americans. Washington, DC: American Association for the Advancement of Science.

Ahkwesahsne Mohawk Board of Education. (1994). Lines & circles. Cornwall, Ontario, Canada: Ahkwesahsne Mohawk Board of Education.

Aikenhead, G.S. (1994). Consequences to learning science through STS: A research perspective. In J. Solomon & G. Aikenhead (Eds.), STS education: International perspectives on reform. New York: Teachers College Press, pp. 169-186.

Aikenhead, G.S. (1996). Science education: Border crossing into the subculture of science. Studies in Science Education, 27, 1-52.

Aikenhead, G.S. (1997a). Teachers, teaching strategies, and culture. In KEDI, Globalization of science education (pre-conference proceedings for the International Conference on Science Education). Seoul, Korea: Korean Educational Development Institute, pp. 133-136.

Aikenhead, G.S. (1997b).Toward a First Nations cross-cultural science and technology curriculum. Science Education, 81, 217-238.

Aikenhead, G.S., & Jegede, O. J. (1998). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. Journal of Research in Science Teaching, (forthcoming).

Arseculeratne, S. N. (1997). Science and technology education and scientific literacy in Sri Lanka: Concepts and problems. In E.W. Jenkins (Ed.), Innovations in science and technology education (Vol. VI). Paris: UNESCO, pp. 251-270.

Atwater, M.M. (1996). Social constructivism: Infusion into the multicultural science education research agenda. Journal of Research in Science Teaching, 33, 821-837.

Bajracharya, H., & Brouwer, W. (1997). A narrative approach to science teaching in Nepal. International Journal of Science Education, 19, 429-446.

Baker, D., & Taylor, P.C.S. (1995). The effect of culture on the learning of science in non-western countries: The results of an integrated research review. International Journal of Science Education, 17, 695-704.

Battiste, M., & Barman, J. (Eds.) (1995). First Nations education in Canada: The circle unfolds Vancouver, Canada: University of British Columbia Press.

Bourdieu, P. (1992). Language and symbolic power. Cambridge, MA: Harvard University Press.

Cajete, G. (1994). Look to the mountain. Durango, CO: Kivaki Press.

Champagne, A.B., Klopfer, L.E., & Anderson, J. (1980). Factors influencing the learning of classical mechanics. American Journal of Physics, 48, 1074-1079.

Cobern, W. W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. Tobin (Ed.), The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science, pp. 51-69.

Cobern, W. W. (1994, January). Thinking about alternative constructions of science and science education. A plenary presentation for the Second Annual Southern African Association for Mathematics and Science Education Research Conference, University of Durban - Westville, Durban, South Africa.

Cobern, W.W. (1996). Worldview theory and conceptual change in science education. Science Education, 80, 579-610.

Cobern, W.W., & Aikenhead, G.S. (1998). Cultural aspects of learning science. In B.J. Fraser & K.G. Tobin (Eds.), International handbook of science education. Dordrecht, The Netherlands: Kluwer Academic Publishers, 39-52.

Contreras, A., & Lee, O. (1990). Differential treatment of students by middle school science teachers: Unintended cultural bias. Science Education, 74(4), 433-444.

Corsiglia, J., & Snively, G. (1995). Global lessons from the traditional science of long-resident peoples. In G. Snively & A. MacKinnon (Eds.), Thinking globally about mathematics and science education. Vancouver, Canada: University of British Columbia, Centre for the Study of Curriculum and Instruction, pp. 25-51.

Costa, V.B. (1993). School science as a rite of passage: A new frame for familiar problems. Journal of Research in Science Teaching, 30, 649-668.

Costa, V.B. (1995). When science is “another world”: Relationships between worlds of family, friends, school, and science. Science Education, 79, 313-333.

Crozier-Hogle, L., & Wilson, D.B. (1996). Surviving in two worlds. Austin, TX: University of Texas Press.

Driver, R. (1979). Cultural diversity and the teaching of science. In H. Trueba & C. Barnett-Mizrahi (Eds.). Bilingual multicultural education and the classroom teacher: From theory to practice. Rowley, MA: Newberry.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 23(7), 5-12.

Feldman, A. & Atkin, J. M. (1993). Research in science education in the USA. Journal of Curriculum Studies, 25, 281-289.

Fensham, P.J. (1992). Science and technology. In P.W. Jackson (Ed.), Handbook of research on curriculum. New York: Macmillan, pp. 789-829.

Geertz, C. (1973). The interpretation of culture. New York: Basic Books.

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

Giroux, H. (1992). Border crossings: Cultural workers and the politics of education. New York: Routledge.

Glaser, R. (1991). The maturing of the relationship between the science of learning and cognition and educational practice. Learning and Instruction, 1, 129-144.

Hawkins, J., & Pea, R.D. (1987). Tools for bridging the cultures of everyday and scientific thinking. Journal of Research in Science Teaching, 24, 291-307.

Henderson, M. (1996, September). Ahkwesahsne math & science pilot project. Canadian Aboriginal Science and Technology Society’s 4th annual conference proceedings. Vancouver, Canada: First Nations House of Learning, University of British Columbia.

Hennessy, S. (1993). Situated cognition and cognitive apprenticeship: Implications for classroom learning. Studies in Science Education, 22, 1-41.

Hewson, M.G. (1988). The ecological context of knowledge: Implications for learning science in developing countries. Journal of Curriculum Studies, 20, 317-326.

Hodson, D. (1993). In search of a rationale for multicultural science education. Science Education, 77, 685-711.

Jegede, O.J. (1989). Toward a philosophical basis for science education of the 1990's: An African view-point. In Don Emil Herget (Ed.), The history and philosophy of science in science teaching. Tallahassee, Florida: Florida State University, pp. 185-198.

Jegede, O. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. Studies in Science Education, 25, 97-137.

Jegede, O. (1996, November). Whose education, whose worldview, and whose framework:? An indigenous perspective on learning. A paper presented at the conference on “Pathways: Indigenous Education: Past, Present, Future,” University of Southern Queensland, Toowoomba, Australia.

Jegede, O. (1997). School science and the development of scientific culture: A review of contemporary science education in Africa. International Journal of Science Education, 19, 1-20.

Jegede, O., et al. (1996, August). Towards a culturally sensitive and relevant science & technology education. A symposium held within the 8th symposium of the International Organization for Science and Technology Education (IOSTE), Edmonton, Canada.

Jegede, O. J. & Okebukola, P. A. O. (1989). Some socio-cultural factors militating against drift towards science and technology in secondary schools. Research in Science and Technological Education, 7, 141-151.

Jegede, O.J., & Okebukola, P.A. (1991). The effect of instruction on socio-cultural belief hindering the learning of science. Journal of Research in Science Teaching, 28, 275-285.

Kaunda, K. (1966). Humanism in Zambia. Lusaka: Zambian IS.

Kawagley, O. (1990). Yup'ik ways of knowing. Canadian Journal of Native Education, 17(2), 5-17.

Kawagley, O. (1995). A Yupiaq worldview. Prospect Heights, IL: Waveland Press.

KEDI (Korean Educational Development Institute). (1997, May). Globalization of science education. Pre-conference proceedings for the International Conference on Science Education, Seoul, Korea.

Kelly, G.J., & Green, J. (in press). The social nature of knowing: Toward a sociocultural perspective on conceptual change and knowledge construction. In B. Guzzetti & C. Hynd (Eds.), Theoretical perspectives on conceptual change. Mahwah, NJ: Lawrence Erlbaum.

Larson, J.O. (1995, April). Fatima's rules and other elements of an unintended chemistry curriculum. Paper presented at the American Educational Research Association annual meeting, San Francisco.

Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). Inarticulate science? Driffield, East Yorkshire, UK: Studies in Education.

Lee, O. (1997a). Diversity and equity for Asian American students in science education. Science Education, 81, 107-122.

Lee, O. (1997b). Scientific literacy for all: What is it, and how can we achieve it? Journal of Research in Science Teaching, 34, 219-222.

Lee, O., Fradd, S.H., & Sutman, F.X. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. Journal of Research in Science Teaching, 32, 797-816.

Linn, M.C., & Burbules, N. (1993). Construction of knowledge and group learning. In K. Tobin (Ed.). The practice of constructivism in science education. Washington, DC: American Association for the Advancement of Science Press.

Loughran, J. & Derry, N. (1997). Researching teaching for understanding: The students' perspective. International Journal of Science Education, 19, 925-938.

Lowe, J.A. (1995). The impact of school science on the world-view of Solomon Island students. Prospects, 15, 653-667.

Lugones, M. (1987). Playfulness, "world"-travelling, and loving perception. Hypatia, 2(2), 3-19.

MacIvor, M. (1995). Redefining science education for Aboriginal students. In M. Battiste & J. Barman (Eds.), First Nations education in Canada: The circle unfolds. Vancouver, Canada: University of British Columbia Press, pp. 73-98.

Maddock, M.N. (1981). Science education: An anthropological viewpoint. Studies in Science Education, 8, 1-26.

McTaggart, R. (1991). Western institutional impediments to Australian Aboriginal education. Journal of Curriculum Studies, 23, 297-325.

Medvitz, A.G. (1985, August). Problems in the application of science education to national development. Paper presented at the Institute of Development Studies, University of Nairobi, Kenya.

Medvitz, A.G. (1996, August). Science, schools and culture: The complexity of reform in science education. A paper presented to the 8th symposium of the International Organization for Science and Technology Education (IOSTE), Edmonton, Canada.

Nelson-Barber, S. & Estrin, E.T. (1995). Culturally responsive mathematics and science education for Native students. San Francisco: Far West Laboratory for Education Research and Development.

Ogawa, M. (1986). Toward a new rationale of science education in a non-western society. European Journal of Science Education, 8, 113-119.

Ogawa, M. (1995). Science education in a multi-science perspective. Science Education, 79, 583-593.

Ogbu, J.U. (1992). Understanding cultural diversity and learning. Educational Researcher, 21(8), 5-14, 24.

Ogunniyi, M. B. (1988). Adapting western science to traditional African culture. International Journal of Science Education, 10, 1-9.

Ogunniyi , M.B., Jegede, O., Ogawa, M., Yandila, C.D., & Oladele, F.K. (1995). Nature of worldview presuppositions among science teachers in Botswanna, Indonesia, Japan, Nigeria, and the Philippines. Journal of Research in Science Teaching, 32, 817-831.

Okebukola, P.A.O. & Jegede, O. J. (1990). Eco-cultural influences upon students' concept attainment in science. Journal of Research in Science Teaching, 27, 661-669.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. Journal of Research in Science Teaching, 29, 791-820.

Pfundt, H., & Duit, R. (1994). Students' alternative frameworks and science education. (4th ed.) Kiel, Germany: Institute for Science Education.

Phelan, P., Davidson, A., & Cao, H. (1991). Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. Anthropology and Education Quarterly, 22, 224-250.

Philips, S.U. (1972). Participant structures and communicative competence: Warm Springs children in community and classroom. In C.B. Cazden, V.P. John, & D. Hymes (Eds.), Functions of language in the classroom. New York: Teachers College Press, pp. 370-394.

Pickering, A. (Ed.) (1992). Science as practice and culture. Chicago: University of Chicago Press.

Pomeroy, D. (1992). Science across cultures: Building bridges between traditional Western and Alaskan Native sciences. In G.L.C. Hills (Ed.), History and philosophy of science in science education Vol. II. Kingston, Ontario, Canada: Faculty of Education, Queen's University, pp. 257-268.

Pomeroy, D. (1994). Science education and cultural diversity: Mapping the field. Studies in Science Education, 24, 49-73.

Pomeroy, D. (1997). STL in a culturally diverse world. In E.W. Jenkins (Ed.), Innovations in science and technology education (Vol. VI). Paris: UNESCO, pp. 59-76.

Rashed, R. (1997). Science as a western phenomenon. In H. Selin (Ed.), Encyclopaedia of the history of science, technology, and medicine in non-western cultures. Dordrecht: The Netherlands, Kluwer Academic Publishers, pp. 884-890.

Ritchie, S.M. (1994). Metaphor as a tool for constructivist science teaching. International Journal of Science Education, 16, 293-303.

Roth, W-M. (1977). From everyday science to science education: How science and technology studies inspired curriculum design and classroom research. Science & Education 6, 373-396.

Roth, W-M., & Alexander, T. (1997) The interaction of students’ scientific and religious discourses: Two case studies. International Journal of Science Education, 19, 125-146.

Shutz, A., & Luckmann, T. (1973). Structures of the life world. London: Heinemann.

Snively, G. (1990). Traditional Native Indian beliefs, cultural values, and science instruction. Canadian Journal of Native Education, 17(1), 44-59.

Snively, G. (1995). Bridging traditional science and western science in the multicultural classroom. In G. Snively & A. MacKinnon (Eds.), Thinking globally about mathematics and science education. Vancouver, Canada: Centre for the Study of Curriculum & Instruction, University of British Columbia, pp. 53-75.

Solomon, J. (1983). Learning about energy: How pupils think in two domains. European Journal of Science Education, 5, 49-59.

Solomon, J. (1987). Social influences on the construction of pupil's understanding of science. Studies in Science Education, 14, 63-82.

Solomon, J. (1992). Getting to know about energy. London: Falmer Press.

Spindler, G. (1987). Education and cultural process: Anthropological approaches (2nd Ed.). Prospect Heights, IL: Waveland Press.

Stairs, A. (1995). Learning processes and teaching roles in Native education: Cultural base and cultural brokerage. In M. Battiste & J. Barman (Eds.), First Nations education in Canada: The circle unfolds. Vancouver, Canada: University of British Columbia Press, pp. 139-153.

Stanley, W.B., & Brickhouse, N.W. (1995). Science education without foundations: A response to Loving. Science Education, 79, 349-354.

Taylor, P.C. & Cobern, W.W. (1998). Towards a critical science education. In W.W. Cobern (Ed.), Cultural perspectives on science education. Dordrecht, The Netherlands: Kluwer Academic Press.

Tobin, K. (1996). Cultural perspectives on the teaching and learning of science. In M. Ogawa (Ed.), Traditional culture, science & technology, and development: Toward a new literacy for science & technology. Tokyo: Research Project STS, Tokyo Institute of Technology, pp. 75-99.

Tobin, K., & McRobbie, C. (1997). Beliefs about the nature of science and the enacted science curriculum. Science & Education, 6, 355-371.

Traweek, S. (1992). Border crossings: Narrative strategies in science studies and among physicists in Tsukuba science city, Japan. In A. Pickering (Ed.), Science as practice and culture. Chicago:March 20, 1998 University of Chicago Press, pp. 429-465.

UNESCO. (1994). The project 2000+ declaration: The way forward. Paris: UNESCO.

Werstch, J.V., & Toma, C. (1992). Discourse and learning in the classroom: A sociocultural approach. In L. Steffe (Rd.). Constructivism in Education. Hilsdale, NJ: Lawrence Erlbaum Associates.

West, L.H., & Pines, A.L. (Eds.) (1985). Cognitive structure and conceptual change. New York: Academic Press.

Wolcott, H.F. (1991). Propriospect and the acquisition of culture. Anthropology and Education Quarterly, 22, 251-273.

Yoong, C.S. (1986). Making science and technology education relevant to youth. In Commonwealth Secretariat (Ed.), Report of the sixth biennial Asia regional workshop. Singapore: Commonwealth Secretariat.

Table 1. An Overview of a Cultural Approach to Science Education

Border Crossings	**Student Categories**	**Cultural Processes of Instruction or Learning (Alternatives to Assimilation or Playing Fatima's Rules)**	**Role of Teacher**	**Collateral Learning**
smooth	Potential Scientists	enculturation	coaching apprentices	none, parallel, or secured
managed	Other Smart Kids	"anthropological" instruction/learning	travel agent culture broker	parallel, simultaneous, or secured
hazardous	"I Don't Know" Students	autonomous acculturation	tour guide culture broker	dependent or simultaneous
impossible	Outsiders	autonomous acculturation	tour guide culture broker	possibly dependent if at all