Teachers' Views on Aboriginal Students Learning Western and Aboriginal Science

Glen Aikenhead
University of Saskatchewan

Bente Huntley
SUNTEP Prince Albert, Saskatchewan

Our interpretive research in northern Saskatchewan inquired into: (a) how science teachers view Western science, (b) how they currently introduce Aboriginal knowledge into their science classrooms, (c) what they believe about the influence of Aboriginal knowledge on learning Western science, and (d) how teachers explain the underrepresentation of Aboriginal people in careers related to science and technology. Barriers to accommodating the cultures of Western and Aboriginal science in classrooms were found to be: conceptual (not recognizing science as a culture); pedagogical (not understanding that students' preconceptions can interfere with learning science and not providing cross-cultural instruction for students); ideological (blaming students for not taking senior science classes); psychological (differing responses to cultural conflict in the classroom); cultural (schools promoting memorization rather than deep understanding, some students feeling disconnected from their Indigenous cultures, and some people not supporting Aboriginal knowledge in science classes); and practical (insufficient resources and support for teachers and students). We found that students were generally forced to navigate between their home culture and the culture of school science on their own. Three key recommendations are proposed for developing culturally responsive curricula, instruction, and assessment.

Introduction

The goal of conventional science teaching has been to transmit to students the knowledge, skills, and values of the scientific community. This content conveys a particular Eurocentric world view because science is a subculture of Western (Euro-American) culture (Pickering, 1992). Thus students with a much different world view—many Aboriginal and non-Aboriginal students alike—face a cross-cultural experience whenever they study Western science (Aikenhead, 1996, 1997; Kawagley, 1990; Ogawa, 1995). This certainly was the case for Aboriginal students who did not speak English as their mother tongue and who lived in isolated communities (Sutherland, 1998; Tufts, 1998). "In some cases, the disparity between home and school environments is so great that some Native American students experience a kind of culture shock which significantly affects their attitudes toward school" (Cajete, 1986, p. 201). According to Aboriginal educators Ermine (1995), MacIvor (1995), and Snow (1974), to transmit a Western scientific world view to these students amounts to cultural assimilation and tends to marginalize and even oppress many students. In response to this and other factors (e.g., irrelevance to everyday

life and to cultural survival, American Association for the Advancement of Science, 1977), Aboriginal students have generally not pursued science courses in the upper grades of high school. Consequently, Aboriginal peoples are extremely underrepresented in careers related to science and technology. How can Aboriginal students gain access to a Western scientific way of knowing without losing something valuable from their own cultural ways of knowing?

One way for teachers to avoid assimilative practices is to integrate students' indigenous knowledge of nature sensitively with the content of Western science (Cajete, 1986; Casebolt, 1972; Jegede, 1995). A culturally sensitive science curriculum would provide "science for all" aimed at developing in students the facility to cross cultural borders between their everyday world of family and friends into the "foreign" culture of school science, without running the risk of assimilation (Aikenhead, 1997). Many students do not cross such borders smoothly because of cultural conflicts (Costa, 1995). They need a teacher who is a "culture-broker" (Stairs, 1995). A culture-broker science teacher will help students move back and forth between their Indigenous culture and the culture of Western science and will help students deal with cultural conflicts that might arise.

As with all reforms in science education, the teacher is the key to success. We need to understand teachers' thinking about culture brokering so we can better collaborate with them as partners in developing new and more appropriate curricula, instruction, and assessment.

To this end our research project investigated science teachers' views on the cultural aspects of Western science and the connection between a student's home culture and the culture of science taught in the classroom. The connection (nexus) was captured by the phrase *science and culture nexus* (SCN). This article focuses on barriers to integrating Aboriginal students' culture into science classrooms. (The issue of integrating non-Aboriginal students' Indigenous culture into science classrooms was addressed by Aikenhead, 1996.)

Theoretical Framework

For the purpose of our research, we adopted a cultural view toward science education—teaching is cultural transmission whereas learning is culture acquisition (Aikenhead, 1997). Because science tends to be a Western cultural icon of prestige, power, progress, and privilege, its culture tends to permeate the culture of those who engage it, with cultural assimilation being one possible consequence. However, many students avoid cultural assimilation by playing "games" that allow them to pass their science course without really understanding the content. The rules of the game are known as "Fatima's rules"; as one teacher in our study said, "Students go with the information and memorize as much as they can without actually doing any new learning." Playing Fatima's rules is not learning in any meaningful way. For example, one of the rules advises us

not to read the textbook but to memorize its boldface 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). Meaningful learning does not result, but instead mere "communicative competence" (Kelly & Green, 1998) for the purpose of getting through a course. Alternatives to assimilation and Fatima's rules must be found if science is to be learned in a culturally sensitive, meaningful way.

When students move from their everyday culture into the culture of school science, the move is called *cultural border crossing.* For the vast majority of students (Aboriginal and non-Aboriginal) whose home world view differs from the world view of school science, cultural border crossing is not smooth. The ease with which students cross cultural borders into school science could probably determine a student's access to Western science. Hazardous and impossible border crossings can cause students to avoid science classes altogether (Costa, 1995).

The cognitive experience of border crossing is captured by a theory called *collateral learning*—learning something in one cultural setting that conflicts with our Indigenous knowledge embedded in a different cultural setting (e.g., Aboriginal students learning Western science). Collateral learning was proposed by Jegede (1995) who used a rainbow as an illustration. In the culture of Western science, students learn that the refraction of light rays by droplets of water causes rainbows, whereas in some African cultures a rainbow signifies a python crossing a river or the death of an important chief. Thus for African students, learning about rainbows in science means constructing a potentially conflicting idea in their long-term memory. How do people resolve this conflict? Four mechanisms (parallel, simultaneous, dependent, and secured collateral learning) were proposed by Jegede (1995) and are illustrated in a recent synthesis of cultural border crossing with collateral learning (Aikenhead & Jegede, 1999).

Methodology

We developed three instruments that systematically gathered quantitative data (25 respondents), qualitative data (7 respondents), and interview data (10 participants) from science teachers across northern Saskatchewan who instructed Aboriginal students in grades 7-12. They taught in rural and urban schools covering a large geographic area across northern Saskatchewan. Some schools were run by Aboriginal communities (band schools) whereas the others were under the jurisdiction of the provincial government. Because we wanted to give voice to Aboriginal participants, a disproportionately high number of Aboriginal teachers participated in the SCN project (6 of the 42 teachers). A more detailed account of the project's methodology can be found in Aikenhead and Huntley (1997).

Based on a preliminary analysis of the quantitative and qualitative questionnaire responses, we designed a semistructured interview instrument. This interview protocol probed salient issues identified by teachers as important to understanding the fundamental positions that teachers held about Aboriginal knowledge, cultural aspects of Western science, their students' success or lack of success with school science, and so on. Ten teachers were interviewed. Interviews were audiotaped and then transcribed. The transcriptions were returned to the participants for them to read and change any part of the transcript to strengthen their anonymity, and for them to clarify or correct any point they made. In this way participants had control over the information that represented their views.

A discussion between interviewer and each teacher provided us with the clearest, most qualified understanding of teachers' views on the connection between science and culture. Consequently, more credence can be placed on the interview data than on the qualitative and quantitative data respectively.

Interviewees

Due to our reliance on the interview data, biographical information describing the 10 interviewees is crucial to the validity of our conclusions. This biographical information provides the reader with a context in which to view the participants' words and the conclusions drawn. The biographical information for Alice, Betty, Brent, Doug, Gary, Jack, Joe, Larry, Rose, and Ted (all pseudonyms) is found in Table 1.

As mentioned above, Aboriginal science teachers were purposefully sought out to give voice to their perspectives. Four of the 10 interviewees were Aboriginal teachers (Alice, Betty, Joe, and Ted). Another purposeful characteristic of all 10 participants was their diverse teaching situation. Betty and Doug worked in an urban setting. The other teachers were in various rural settings: Larry and Rose taught for a large province-operated school division, whereas Jack, Alice, Brent, Joe, Ted, and Gary taught in band-operated schools.

Results

The teachers expressed diverse and sometimes incompatible views. These results are succinctly described here. The interview data support four general conclusions:

1. Teachers generally viewed Western science as course content or as a way of exploring nature, not as a foreign culture as experienced by many of their students.
2. Aboriginal knowledge was respected by science teachers, but only a token amount was added onto, but not integrated with, school science.

Table 1. Biographical Data from the Interviewees

Alice is a female Aboriginal teacher who has taught grades 7-9 science for a band-controlled school in the south for five years and in the north for one year. Alice has been teaching science for a total of six years. The main language spoken at home and work is English.

Betty is a female Aboriginal teacher who has taught grades 7-9 science in an urban school for the last two years. The school has a high percentage of Aboriginal students. The main language spoken at work and home is English. Betty has lived in the community for 18 years.

Brent is a male non-Aboriginal teacher who has lived and taught in a band-controlled school for the past year. The school is situated near an urban center. The main language spoken at home and work is English. Brent has lived in the surrounding community for over 20 years.

Doug is a male non-Aboriginal teacher who has lived in a city for 55 years. He has taught science for 30 years in this community. The main language spoken at home and work is English. The high school where Doug teaches has a small percentage of Aboriginal students. Doug teaches grades 10-12 sciences.

Gary is a male non-Aboriginal teacher who has lived and taught in a northern community for the past 12 years. He has taught science for 21 years and teaches grades 10-12 sciences in a band-controlled school. The main language spoken at home and work is English; however, a high percentage of the students speak Cree at school. Gary holds a Bachelor of Science degree as well as a BEd.

Jack is a male non-Aboriginal teacher who has taught grades 10-12 science in a band-controlled school for two years. Jack has lived and worked in the community less than five years but has more than 20 years teaching experience. Jack's field of expertise is not science and he has only spent five years throughout his career teaching in the area of science. The main language spoken at home and at work is English.

Joe is a male Aboriginal teacher who has taught science for 15 years. He has taught grades 7-9 science in remote northern band schools for the past seven years. The main language spoken at home and work is Cree. As the school principal Joe spends a half-day on administration and a half-day teaching. Science is one of the subjects Joe teaches to a multigraded classroom.

Larry is a male non-Aboriginal teacher who has taught grades 7-9 science in a northern community for the last five years. The main language spoken at home and at work is English. The school, however, has a high percentage of Aboriginal students: Dene, Cree, Metis, and European ancestry. Larry teaches all subject areas but science is one of his areas of expertise.

Rose is a female non-Aboriginal teacher who has lived and taught in a remote northern community for the past three years. The school has an extremely high percentage of Aboriginal students. The main language spoken at home is English, but at school it is Dene. Rose majored in science in university and now teaches grades 7-9.

Ted is a male Aboriginal teacher who has lived and taught in a northern band school for the past three years. Ted taught grades 7-9 subjects, including science, during his stay in this community. The main language spoken at home and work is English although a large percentage of students speak Cree, their first language, at school.

3. Teachers thought that the act of learning science was unrelated to their students' Aboriginal world views.
4. Students' disinterest in pursuing science careers was either unexplainable by the interviewees or was blamed on student deficits. Few teachers blamed their curriculum and teaching.

Each of these points is discussed in the sections that follow.

We should point out that teachers held similar ideas about the meaning of culture. Our interviewees generally agreed that culture was a way of thinking, of viewing the world, and of interacting with the world: in short, a way of living. Some participants talked about different subcultures and about how culture changes depending on the circumstances.

Views on Western Science

Although no teacher attempted to define science during the interviews, the word came up on many occasions, of course. From these occasions it became evident that different people had different ideas about what science means, and these meanings would shift when the context changed (a normal linguistic practice). Depending on the context, the following meanings of science could be found in the interview data. Science is:

1. Any knowledge about nature irrespective of the knowledge system used (e.g., "science is everywhere," "children learn science on the trap lines," and "Aboriginal science").
2. The canonical knowledge, skills, and values of Western science as found in university science courses and in school curricula.
3. A school subject to be passed for credit.
4. Processes and products usually identified as technology by the academic social science community.
5. An aspect of Euro-American culture, or a subculture.

The reader must be vigilant and sensitive to these five different meanings of science found in all teachers' statements about the connection between science and culture.

Most respondents equated science with technology by associating science with activities and goals normally considered to belong to technology (meaning number 4 above). The social science literature consistently points out how science and technology are quite different enterprises, although they interact considerably (Ziman, 1984). Thus sometimes the phrase *interaction of science and culture* may mean the same thing as interaction of technology and culture for most of the teachers.

On the one hand, many of the 25 teachers (72%) responding to the quantitative SCN instrument acknowledged that science could be "a rational perceiving of reality," an expression that Ogawa (1995) used for definition number 1 above. On the other hand, fewer of these teachers subscribed to meaning 5, which recognizes science as a cultural phenomenon. The cultural view of science was acknowledged by only half the science teachers in our study.

The connection between Western science and Euro-American culture was acknowledged by only some of the teachers, but even then it seemed restricted to an intellectual realm. Their views never addressed classroom practice, where the day-to-day challenges are faced by Aboriginal students when learning science. The cultural status of science seems to have little currency for teachers.

The beliefs of the teachers we interviewed seemed on the surface to be completely at odds with the views of Aboriginal educators, who view science as a part of Western "progress that has oppressed Aboriginal peoples since the time of contact" (summarized in Aikenhead, 1997). This discrepancy between the teachers' views and Aboriginal experiences would seem to create an invisible barrier to Western science content for Aboriginal students. A teacher cannot accommodate culture effectively in a science classroom without appreciating the cultural nature of that science content.

Although the teachers were unanimous in rejecting the idea that their science classrooms purposely assimilated Aboriginal students into a Western world view, the teachers may have unintentionally worked toward assimilating some students by not intentionally treating science as a cultural phenomenon. Teachers generally viewed Western science as course content to teach or as a way of exploring nature, not as foreign culture that many of their students experienced.

Introduction of Aboriginal Knowledge into Science Classrooms

Teachers' efforts were directed toward adding a measure of Aboriginal content to conventional science instruction, toward participating in school-wide programs that taught Aboriginal knowledge, or toward engaging students in science activities that made connections to students' everyday worlds. However encouraging these approaches are, they tend to force students to negotiate *on their own* the transitions between home culture and the culture of school science. Aboriginal knowledge was respected by the science teachers in our study, but only a token amount was added onto, but not integrated with, school science. This situation varied from community to community and depended on the culture of the school.

Rose and Alice, a non-Aboriginal and Aboriginal teacher respectively, put a high premium on incorporating Aboriginal knowledge into the school program, more than most other interviewees. "It builds student self-esteem," Rose claimed (48) (the numbers identify the lines on the transcripts where the raw data may be found). Their incorporation of Aboriginal knowledge drew principally on community elders as the educational resource. Because the number of available elders is limited, it is difficult to access this valuable resource (Alice, 28). This problem is coupled with the fact that most print and audiovisual materials known to the teachers are relevant to Native American students in the United States,

not to Cree, Dene, Metis, or other Aboriginal students in Saskatchewan. This lack of resources was cited by most of the other participants as the main reason that only a token amount of Aboriginal knowledge was introduced into their science programs.

Betty grew up in a central Saskatchewan Aboriginal community. She too put a high priority on incorporating Aboriginal knowledge into her science classroom so students could make connections to their lives and culture while engaging in hands-on "sciencing." However, the Aboriginal community in which Betty was teaching was not the community where she grew up. This made a world of difference to how much Aboriginal knowledge she could incorporate. In her words:

> I work with an Aboriginal teacher who is always bringing in people. She's older than me and she's lived here forever and knows all these people personally. I don't actually live here; close to this area. I don't know of the elders personally. I don't feel all that comfortable approaching them when I don't know them really well. I think there is a lot of non-Aboriginal teachers who feel that way. (350-356)

Her advice to herself is to have students learn the community's Aboriginal knowledge on their own and then teach the class what they have learned.

On the other hand, Alice (who has taught five years in her community) took more personal responsibility to learn from resource people: "If I couldn't find someone to come in, I would go and ask someone and then bring that back; tell the kids what I've learned" (Alice, 34-36). Whereas Alice's school made a conscious effort to teach both Western science and Aboriginal knowledge in science classes, Betty's school did not have that commitment, and hence Betty felt almost all the responsibility falling on her shoulders.

Jack (12-23) and Brent (230) were the only teachers interviewed who distanced themselves and their teaching from Aboriginal knowledge. Several of the other teachers mentioned that their classroom was the only science classroom in the school where Aboriginal knowledge was welcome.

Other problems that militate against the incorporation of Aboriginal knowledge into science instruction for some communities were identified by Brent and Joe. The Aboriginal students in their communities are so disconnected from their culture that incorporating Aboriginal knowledge into the science classroom would not really seem relevant to them. Joe pointed to the 50:50 split in his community among the Aboriginal parents, where half of them wanted Aboriginal knowledge taught in school and the other half were against it (48). Nevertheless, he felt that Aboriginal knowledge was evident in his school's science classrooms. Joe valued his Aboriginal knowledge as being scientific. However, several teachers mentioned that their students did not value their own Aboriginal knowledge as worthy of equal status to school science.

Gary and Ted both suggested that the Anglican church had succeeded in almost eliminating Aboriginal spirituality in the community where they presently taught. Ted pointed out that traditional ceremonies were conducted in secret if at all. Consequently, when bringing Aboriginal knowledge into his classroom (framed in a holistic interconnection among all things and all knowledge of Mother Earth), Gary felt pressured to exclude references to spirituality (216), but he saw value in considering both Western and Aboriginal views because it developed critical thinking skills (570). The apparent contradiction between compartmentalized and holistic knowledge went unnoticed.

The picture emerging from the interviews is an expressed openness to include Aboriginal knowledge in the science program (the Saskatchewan science curriculum was cited by several teachers as encouraging it), but in practice little or moderate headway is being made except for a few unique instances (Rose and Alice).

Aboriginal Knowledge and Success at Learning Science

Our non-Aboriginal teachers were articulate and persuasive in denying any cultural conflict between Aboriginal and scientific ways of knowing. All teachers interviewed, including the four Aboriginal teachers, thought that the ease of learning science had nothing to do with students' possessing an Aboriginal world view. Teachers firmly believed that learning science posed no risk to losing something valuable from students' own culture. These ideas arose in response to such questions as: Does the possession of Aboriginal knowledge inhibit students from learning science? If Aboriginal students do master science, do they lose something valuable from their own culture? To what extent is science a foreign culture to Aboriginal students?

Most (72%) of the 25 teachers responding to the quantitative SCN instrument disagreed with the statement "Students' belief in everyday common knowledge inhibits their learning science" (a statement with which the research community would agree based on supporting evidence amassed over the last 20 years, Driver, Asoko, Leach, Mortimer, & Scott, 1994). Teachers' views and empirical evidence seem to be at odds. Most of the 10 interviewees would probably have disagreed with the statement as well, but their reasons would vary considerably. For instance, Joe did not separate the two knowledge systems in his mind (scientific and Aboriginal) in the sense that he believed that an individual could take something from each type of knowledge system (140). Gary claimed that Aboriginal knowledge is "the best teaching tool you could use" (355). He added: If students "make no effort to get involved in the information, they'll be ignorant" (369); thus there was no problem of Aboriginal knowledge inhibiting students' learning of science as long as student made an effort! Brent recognized that traditional values do conflict with chemistry theory, but pointed out that one can understand an idea (for the purpose

of passing tests and getting to university) but not believe it. The distinction between understanding and believing a scientific idea seemed to be fundamental to learning science. Gary and others also alluded to this distinction.

Along similar lines of thought, Alice recognized the potential conflict between scientific reductionism and the commonsense holistic way of Aboriginal students (70-77), but she claimed that this potential conflict did not inhibit students in her community from learning science (117). She advised teachers to relate science to students' interests, to engage them in activities in which they learn science skills, and then have students transfer those skills to a written assignment (228).

Rose gave a much different reason. Learning science is not inhibited by students' Aboriginal culture in her community because many students do not know the Aboriginal knowledge in the first place. Instead they believe in Western culture, a pervasive influence of the Catholic church, she claimed (109-123). Rose also blamed the problem on the social institution of schooling: students are "confused about their own traditions and the whole Western world coming in with its institutionalized education" (219-221).

Jack cited students' lack of discipline and lack of language and math skills as the inhibitors to learning science (92-105). Larry tended to agree with Jack (472) but stressed a much more fundamental inhibitor—a lack of family support for school learning (414-422).

And finally, Betty added a few more reasons or conditions that would inhibit learning: the attitude that science is "just another point of view" so why learn it? (199); instruction that relies on the textbook and note-writing (125); and content that explicitly rejects Aboriginal beliefs (248). According to Betty, learning will be facilitated if a teacher "meshes" Aboriginal and science knowledge (219) making many connections between the two (255). She claimed that the two biggest inhibitors to learning science are disruptive students when they play at science (486), and students not having the skills or desire to write an intelligent response about what they were doing in a hands-on activity (488).

The science teachers participating in our study tended to reject any idea of there being any negative consequences to Aboriginal students learning Western science. Ted maintained a basic belief about learning: "You don't have to lose something when you gain something" (412). Science will enhance what you already know. He attributed alienation not to science, but to the Anglican church, which nearly eliminated traditional spirituality from his community, although this spirituality is slowly returning (144).

Joe was not as optimistic as Ted. Joe warned of the danger of losing something valuable from Aboriginal culture and the danger of science dominating one's thinking if it was not watched and guarded against

(144-154). One way to guard against it is to differentiate constantly between each set of beliefs, Aboriginal and scientific (157), while integrating knowledge from both domains (140).

Betty and Alice both emphasized individual differences among students; that is, the consequences of mastering science will be different for different students. Some students will lose something valuable of their own culture if they master science, but others will not. Betty and Alice identified various types students: those "keeners" who naturally and easily catch on to science (Betty, 227), those "keeners" who are curious but have to work at understanding science (a group Betty identified with, 230), and those who just memorize to get through by playing Fatima's rules (Alice, 180). Alice also expressed a fundamental tenet to her idea of learning: "What students believe in has to be affirmed some way. You can't separate it" (266). Alice's view reinforces Betty's idea that the two knowledge systems (scientific and Aboriginal ways of knowing) need to be meshed, a view that appears to contradict Joe's belief in differentiating between each way of knowing. The opposing positions can be identified as two ends of the spectrum of collateral learning.

Doug presented a similar view by emphasizing the idea that if science dominated one's way of thinking, that does not necessarily mean that one is alienated from one's culture (363).

Rose believed that the assimilation into Western culture (mostly through technology such as television) has already generated a "Eurocentric way" (137) in the minds of Aboriginal students who therefore see science as logical common sense. As a consequence, science dominates their thinking already (192).

Gary cited his own experience of learning Aboriginal knowledge over the years without it dominating his thinking. He expects that Aboriginal students can handle scientific knowledge just as he handled Aboriginal knowledge (428). (Gary's privileged status as a teacher did not enter the discussion.)

A different picture was painted by Larry. He too disagreed that mastering science would cause students to lose something valuable of their own culture (40), but Larry also talked about students switching back and forth between the two ways of knowing. Each way of knowing was like having ideas "in different pockets" (206, 288, 305). Here Larry articulates a fundamental view of separating the two knowledge systems. He goes on to argue that science dominates one's thinking not because of the potency of scientific knowledge, but because Western culture strongly dominates other cultures, period; thus Western culture, not science, marginalizes Aboriginal peoples (65). According to Larry, individual differences and community circumstances are influential, an idea that found support from Betty and Alice.

When the issue of Aboriginal versus scientific knowledge arises, as it did in the discussions above, different viewpoints begin to surface about how to handle two different, potentially conflicting knowledge systems. At one extreme is Joe's and Betty's approach of meshing the two knowledge systems together (secured collateral learning; Aikenhead and Jegede, 1999), while at the opposite extreme is Brent's and Larry's approach of segregating the two (parallel collateral learning).

To what extent is science a foreign culture to Aboriginal students? Based on all the data, we came to the conclusion that, in general, teachers thought that learning science was unrelated to students' possessing an Aboriginal world view. Teachers identified other causes for student difficulties learning Western science.

Explaining the Lack of Participation

If, as our participants believed, science is no more foreign to Aboriginal students than it is to their non-Aboriginal counterparts in other schools (a belief contradicted by Sutherland's [1998] recent research with Manitoba Cree communities), then how did our participants explain why there are so few Aboriginal scientists and engineers? Why do so few Aboriginal students continue to take science in high school and university?

Students' disinterest in pursuing science- and engineering-related careers was at first unexplainable by half the interviewees. The other half blamed student deficits, for example, inadequacies in their self-confidence, language and math skills, academic orientation, and strength of family culture and support (all described above). Not one teacher broke through this wall of excuses to see a more fundamental issue of cultural conflict for many Aboriginal students in school science. "Blaming the victim" was a strategy identified in South Africa by Naidoo and Savage (1998): "Conveniently, equity becomes seen in terms of individual failure to take advantage of opportunities, not as a failure of society to prepare individuals to do so" (p. 83).

This theme was repeated in various ways by our interviewees, although some did recognize societal influences on student participation in upper-level science courses. Alice (324), for instance, suggested it might depend on the community because science is not stressed in some schools, but also some students seem intimidated by the required skills in science (195). Rose surmised a fear of math and a lack of confidence (178). She also discussed what science meant to students: a subject to be passed and not a rational perceiving of reality (a meaning-making system connecting ideas together, 404). Who wants to make a career out of an artificial school subject? (211)

Betty believed that science had been used in the past to reject Aboriginal knowledge, and this would discourage Aboriginal students from taking science seriously (284). Similarly in a US study of grade 3 children, Schilk, Arewa, Thomson, and White (1995) concluded, "The

perceptions Indian students had of scientists, largely dictated by popular media, were in direct conflict with their Iroquois values" (p. 3):

Interviewer: Do you think you could be a scientist?
Clint: That's not something Indians do. I couldn't hurt things or blow things up.

This view found support in Gary (480), who suggested that science careers are associated with the White power structure of Canada. Science careers are rejected by Aboriginal students who feel their people have been abused by science.

Ted explained that high school science is associated with going to university. University life is quite a change for students (leaving the safety of home to go to the big city), too much change to be comfortable (453). Thus there was little incentive in general for his students to be interested in a science or engineering career.

Joe commented on the conflict between the scientific value of questioning everything and the traditional home value of accepting things as they are (166). The conflict increases an Aboriginal student's discomfort with science as a life career.

Gary's main reason for so few Aboriginal students attending university was the poor prospects for a good job for university graduates (473). Employment is more secure through the trades, not through academics (482). High school science seems too hard and too abstract for all students (488). When science careers prove more useful to students, more students will follow those careers (440).

It is interesting to note that the potential cultural conflicts between science and Aboriginal knowledge (conflicts that seemed to be relegated to a low priority in earlier discussions) were given greater credence by several teachers when they talked about students' avoidance of science classes and careers.

Not many teachers in our study blamed their curriculum and teaching. After all, if teachers believe that Aboriginal world views are no barrier to gaining access to Western science, then it follows that access must be related to circumstances other than differing world views. At the present time, therefore, many of our participants would probably not embrace the need to become culture-brokers to help Aboriginal students negotiate cultural borders between their family life culture and school science culture.

However, by listening to those teachers who did mention deficiencies in their curriculum and teaching, we gain insight into what might help Aboriginal students overcome the cultural boundaries identified by Aboriginal writers (MacIvor, 1995).

Conclusions

Cajete (1986) argued that an absence of cross-cultural teaching in science classes constitutes a major barrier to integrating students' Aboriginal cul-

ture into science classrooms. We argue above that this forces students to navigate on their own between their home culture and the culture of school science. Only a few interviewees gave evidence of explicit cross-cultural teaching.

Students whose families support an Aboriginal culture will probably prosper from a science curriculum framed by an Aboriginal world view, whereas students who are disconnected from their cultural roots may not find such a curriculum to be relevant. Several teachers (Betty, Brent, and Rose) lamented that few Aboriginal students felt connected to nature (in spite of living in Northern communities) and too few felt connected to their own Aboriginal culture. Such feelings of disconnectedness have preoccupied many Aboriginal educators (Battiste & Barman, 1995; Deyhle & Swisher, 1997). The problem of disconnectedness to nature and Aboriginal culture is a barrier to accommodating Aboriginal culture in science classrooms. The barrier challenges science educators to engage their community in efforts to reestablish traditional values, knowledge, and language, so students will feel more connected to their Aboriginal cultures.

Another theme was identified and underscored by several teachers: the importance of making connections between science content and the students' everyday lives. Betty (116), Alice (146), Rose (209), and Larry (503) described specific instances of significant connections. According to many of our interviewees, science fairs and "Science Olympics" seem to have a major impact on students. Evidently, some Saskatchewan Aboriginal students experience science lessons and activities at school that are meaningful and beneficial to them. According to their teachers, school science comes alive for these students during these events.

Why do Aboriginal students avoid science in high school and university? About half of our interviewees initially said they had no idea. They could not confidently make sense of the problem, let alone resolve it. This constitutes another barrier. Teachers need to develop ways to encourage students to continue in science. One promising idea is to change the science courses themselves into culturally sensitive curricula, instruction, and assessment that make students feel more comfortable border-crossing between their own culture and the culture of school science.

The interviews indicated that when the teachers experienced conflict between science and Aboriginal knowledge, they had diverse ways of dealing with this conflict. Their diverse ways can be described by different types of collateral learning (parallel and secured). We should anticipate both a match and a mismatch between students and their teachers in terms of the type of collateral learning they are comfortable with. A mismatch may create a barrier to culturally responsive teaching. However, if teachers are aware of their own preferred type of collateral learning and are aware of the alternative types preferred by some of their students, then

teachers' instruction can be more responsive to the needs of their students. This sensitivity will improve the culture-broker role of science teachers.

Teachers who want Aboriginal students to succeed in science must not be undermined by a lack of instructional resources that accommodate Aboriginal knowledge in science classrooms or by a pervasive school culture that inadvertently promotes Fatima's rules. The interview data were replete with constraints to successful science instruction. These barriers will not be diminished simply by adopting a cultural perspective on student learning, but such a perspective gives us new ways to circumvent some of those barriers creatively.

Recommendations

Instances of culturally responsive curriculum, instruction, and assessment were evident intermittently in our research data. The recommendations below speak to expanding the frequency of those examples so they become conventional practice rather than the celebrated exception. These normative statements represent a partial answer to the question: How can Aboriginal students gain access to a Western scientific way of knowing without losing something valuable from their own cultural ways of knowing? The recommendations synthesize the writings of Aboriginal educators in the context of our conversations with teachers. (A more detailed formulation of these recommendations is found in Aikenhead & Huntley, 1997.)

1. School science should validate and teach Aboriginal knowledge to a significant degree and should combine it with Western science knowledge. Our participants spoke of making connections between school science and the students' everyday lives. Aboriginal language/knowledge/culture must be seen by students as an asset to learning Western science, not as a liability. An Aboriginal world view could frame a science curriculum in which appropriate scientific knowledge, skills, and values are studied in a cross-cultural way.
2. A group of teachers who are amenable to fulfilling the role of culture-broker should be identified and then organized into a network with other educators. This network should collaboratively carry out research and development (R & D) individually in classrooms and together as a group. Teachers need to be given the resources to run community-based science committees that will help them develop culturally responsive teaching and assessment practices and help them modify other teaching materials to suit the local culture, including the local language.
3. Children in elementary schools (grades 1-6) should experience enough hands-on materials to develop routines of proper behavior around materials in classrooms. They should also learn that some of their hands-on experiences with natural phenomena are genuine instances of playing in the culture of Western science, and that some ex-

periences relate to their Elders' knowledge of nature, a knowledge that constitutes a valid way of knowing about their world.

By implementing these recommendations, school jurisdictions will probably dismantle some major barriers to accommodating Aboriginal culture in science classrooms.

Given the diverse views of our 10 interviewees, one might anticipate opposition from some science teachers: those who believe that all knowledge of nature can be subsumed under Western science, those who subscribe to a school culture that cultivates playing Fatima's rules, and those who will not distinguish between Western and Aboriginal knowledge because of their quest for one holistic knowledge system to explain nature. Knowing about these potential barriers ahead of time should strengthen the wisdom of educators as they address the needs of Aboriginal students. The results of this study will help educators plan collaborative projects informed by teachers' views on the nexus between science and culture.

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