A CULTURAL PERSPECTIVE OF CONCEPTUAL CHANGE: RE-EXAMINING THE GOAL OF SCIENCE EDUCATION

GEORGE ZHOU *University of Windsor*

ABSTRACT. The goal of science education is usually meant to develop students' basic knowledge, skills, and scientific attitudes as stated in many countries' curriculum documents, with little consideration of what backgrounds students bring into the classroom. A cultural approach to education has challenged this universal goal of science education. This paper provides a cultural analysis of conceptual change and recommends an argument approach to teaching for conceptual advancement. It argues that the outcome of classroom discourse cannot be oriented to be a replacement of students' intuitive conceptions with scientific notions, rather coexistence between scientific understanding and culture/experience-based views is considered to be a more reasonable and realistic goal.

UNE PERSPECTIVE CULTURELLE DES CHANGEMENTS CONCEPTUELS: RÉEXAMINER LE BUT DE L'ENSEIGNEMENT DES SCIENCES

RÉSUMÉ. Le but de l'enseignement des sciences, tel que défini dans les programmes d'enseignement de plusieurs pays, est habituellement de développer les connaissances de base, compétences et attitudes scientifiques des élèves et ce, sans égard pour leur savoir préalable. Une approche culturelle à l'enseignement a bouleversé ce but universel de l'enseignement des sciences. Cet article analyse sur une base culturelle le changement conceptuel et recommande une approche argumentaire comme méthode éducative favorisant l'évolution conceptuelle. L'auteur y avance que les résultats des débats faits en classe ne peuvent être orientés pour reprogrammer les conceptions intuitives des élèves par des notions scientifiques. En fait, Zhou soutient qu'un but sensé et réaliste est une cohabitation de la compréhension scientifique et des points de vue personnels et culturels sur la science.

Born and raised in the countryside of China, my childhood was full of ghost stories. I heard of them from my parents, neighbors, relatives, and classmates. I still clearly remember one story my mother told me about 35 years ago. The story took place one late evening when a farmer passed by a graveyard on his way home. He suddenly got lost, and many ghosts appeared around him covering his eyes with hands, filling his mouth with dirt, and pulling him off the road by his clothes. He tried to escape, but ended up moving from one grave to another. He became so scared that he shouted loudly for help. People in the village came out beating drums and striking gongs to scare the ghosts away. Besides such oral stories, I learned about ghosts from books, radios, TV shows, and movies. There is one famous book entitled *Liao Zhai Zhi Yi*. It was originally completed over 300 years ago and recorded many ghost stories the author had collected. The book has been adapted to movies and children books.

I experienced ghost culture intensively during the Chinese New Year celebration, the Spring Festival. On the wall of our house hung a photo of my grandmother who passed away when I was in elementary school. On New Year's Eve, my parents placed food in front of the photo, burned paper money, and then kowtowed before the photo, murmuring in a hard-to-hear voice something like "collect your money," "take care," or "bless the family please!" On New Year's Day, my father always took my brothers and me to join a group that consisted of men from his brothers' and cousins' families. The group went to the family grave yard and performed the same ritual in front of the graves of our ancestors as what my parents did with the photo of my grandmother. During the Spring Festival, my parents, like other farmers, posted red couplets on their house doors with content varying widely from the blessing of good luck to praise of government policies. Why red? Red symbolizes happiness and prosperity in Chinese culture and farmers believe ghosts are afraid of the color red. Another common thing to do during the Spring Festival is to light firecrackers. Firecrackers are also thought to frighten away stray ghosts. In this kind of social and cultural environment, the concept of ghost was developed and rooted deeply in my mind. I would even turn back from time to time to check whether something was following me while I walked alone in the evening. I can still remember the Spring Festival when I lit firecrackers at every corner of our yard and, in the two vacant rooms of our house because I believed that stray ghosts tended to stay in quiet, dark, and remote areas.

When I entered into middle school, however, my biology teachers told me that ghosts did not exist and that everything ended after death. My Chinese language textbook included articles that stated the nonexistence of ghosts. I began to talk as an atheist, especially when I moved to the city for high school. I rarely heard and thought about ghosts in the city, and the concept of ghosts became blurry over time.

Even now, after many years of university education, including extensive academic training in science and professional experience in science education, this traditional knowledge about ghosts remains deeply embedded in me. In 1996, I visited my parents during a New Year's Day work break. One of my grandmothers had passed away that winter. I arrived at the village in an evening and wanted to visit this grandmother's family to offer my condolences for their loss. My mother and brother advised me to wait until the next morning considering the recent death and the understanding that ghosts were more active at night. I indeed waited till the next morning.

A reflection on my life journey with the concept of ghosts pushes me to question the effectiveness of education practices that aim to completely eliminate a person's views about something, particularly when these views are deeply rooted in his or her ethnic-racial culture. This inspired me to critically look at an important research topic in science education: conceptual change. A large volume of research over the last two decades of the 20th century has convincingly documented that students come into the classroom with their own ideas on many scientific topics (e.g. Driver, Guesne, & Tiberghien, 1985). However, the efforts to replace students' ideas with scientific notions have been reported to be very difficult in many cases (e.g. Clement, 1982). Cultural studies of science education since the late 1990s have examined student learning in cases where students' life-world culture clashes with the culture of Western science, and there has been an attempt to integrate indigenous knowledge into the Western-science dominated school curriculum (Aikenhead, 2006). These studies claim that the traditional science education works to effectively colonize students by assimilating them into the culture of Western science. This attempt at colonization largely fails since it makes many students feel alienated from science. Postcolonial thinking encourages one to ask such questions as how the topic of conceptual change can be viewed differently and what can be considered as the goal of science education. Some scholars (Aikenhead & Jedege, 1999; Jedege, 1995, 1997) have employed the notions of border crossing and collateral learning in order to describe the learning of Western science which is contradictory to indigenous knowledge. However, the literature still has gaps on such questions as to how the two contradictory knowledge systems are impacted by each other as a result of cross-cultural learning and what classroom practices would be appropriate to address this type of learning.

To tackle these important and timely questions, this paper starts with a critical review of conceptual change literature published in the past three decades, then goes on to discuss the pre-assumed goal of science education underlined in this literature. A postcolonial framework is used to deconstruct the past literature on conceptual change and propose a cultural approach to looking at this topic. Finally, this paper advocates for a new perspective about the goal of science education and recommends an argument approach to teaching for conceptual advancement with a belief that the instruction of scientific models is incomplete without exposing students to the distinctions between the scientific and cultural ways of constructing knowledge claims.

"COLD" AND "WARM" MODELS OF CONCEPTUAL CHANGE

Students come to the school with their own understanding of the world (Driver, Guesne, & Tiberghien, 1985). Relevant literature has referred to students' ideas as "preconceptions" (Clement, 1982), "misconceptions" (Helm 1980), "naïve or intuitive ideas" (Osborne & Freyberg, 1985), "alternative frameworks" (Driver & Erickson, 1983), or "alternative conceptions" (Gilbert & Watts, 1983). Taking into consideration that students' conceptions are formed before receiving formal instruction in class, this paper will use the term "preconception." A plethora of studies have been conducted to identify preconceptions in numerous scientific content areas (e.g. Bar, Zinn, & Rubin, 1997; Bishop & Anderson, 1990; Clement, 1982; McCloskey, 1983). A common conclusion from these studies is that preconceptions are often at odds with scientific ideas and continue to persist following traditional instruction. The purpose of science teaching was therefore assumed to be a replacement of students' less acceptable conceptions by more sophisticated scientific concepts capable of accounting for phenomena where preconceptions were unable to do so. This replacement was called conceptual change.

"Cold" model

Scholars have proposed models and strategies to describe or facilitate teaching for conceptual change. One of the earliest and well-known conceptual change models came from Posner and his colleagues (Posner, Strike, Hewson, & Gertzog, 1982). Inspired by Kuhn's (1970) theory of scientific revolution, Posner and his colleagues stated that there were several cognitive conditions that must be fulfilled before any conceptual change can occur. These conditions could be briefly described in terms of students' dissatisfaction with the old conception and the intelligibility, plausibility, and fruitfulness of the new conception. This model attracted much attention from science educators. Most theoretical analyses and practical strategies for conceptual change constructed during the 1980s and 1990s were based on or closely related to this model (E. L. Smith, Blakeslee, & Anderson, 1993). For example, Nussbaum and Novick (1981) suggested a three step approach to promote conceptual change: (a) making children's alternative frameworks explicit to them, b) inducing dissatisfaction by presenting evidence that does not fit, (c) presenting the new framework and explaining how it can account for the anomaly. These proposed teaching strategies share a common process that involves creating cognitive conflict before providing a new framework (Hewson & Hewson, 1988).

Empirical studies which attempt to bridge the gap between a personally held concept and the scientific view, however, have generally revealed that preconceptions are resistant to change (Clement, 1982). Studies have also documented that preconceptions are apparently changed in school settings but may quickly reassert themselves in the broader context of daily life (Redish & Steinberg, 1999). In addition, Georghiades (2000) reminds us that the conceptual changes reported in the literature are not necessarily permanent changes. Most of these claimed changes were actually measured right after the instruction. There was no clear distinction about whether these changes reflected students' profound change in thinking or a process of simply following what teachers instructed in some particular academic contexts, such as exams. The difficulty that practical efforts have encountered in facilitating conceptual change has forced some scholars to question the plausibility of Posner et al.'s model.

Pintrich, Marx, and Boyle (1993) criticized Posner et al.'s model as a "cold" model because it overlooks the non-rational characteristics of learning. This omission is clearly reflected in one statement that Posner and his colleagues made in their paper: "Our central commitment in this study is that learning is a rational activity" (Posner et al., 1982, p. 212). According to this model, when students meet new experiences in the classroom which do not match their existing mental structures, they will feel dissatisfied and be willing to accept new concepts to overcome this conflict. In other words, conceptual understanding is seen as the goal of student learning. However, the assumption that students approach their classroom learning with a rational goal of making sense of the information and coordinating it with their prior conceptions may not be accurate. Actually, students have many social goals in the school context besides academic understanding such as making friends, impressing peers, or pleasing instructors (Wentzel, 1991), which can turn them away from any in-depth intellectual engagement with the curriculum content. Students may passively face conceptual discrepancy by just memorizing the scientific concepts without understanding them (Larson, 1995; Loughran & Derry, 1997; Watson & Konicek, 1990). The normative goal theory has made this point very clear since it states that students with the goal of mastery learning are more engaged in deeper cognitive processing and tend to use more sophisticated cognitive strategies. In contrast, students with performance-orientated goals more often use surface processing and have less cognitive engagement (Ames, 1992; Dweck & Leggett, 1988; Nolen, 1988, 1996; Pintrich & De Groot, 1990).

Posner et al.'s model can also be criticized for its lack of a clear social dimension in learning. The model predicts that when students become dissatisfied with their original beliefs, they will try to find an alternative one that is intelligible, plausible, and fruitful. This description focuses on personal cognition and implies that all reasoning happens within an individual's mind. However, there are numerous theoretical articulations suggesting that an individual's learning in the classroom is not isolated, but greatly influenced by interactions with others. For Piaget (1970, 1973), social interaction is seen as a requirement for children to construct social knowledge and as a resource for cognitive disequilibrium that leads to knowledge reconstruction. In Vygotsky's account, all higher mental functions originate from social relationships (Vygotsky, 1978). Besides these theoretical articulations, experimental studies have actually documented the merits of collaborative learning in the school setting. Barbosa, Jofili, and Watts (2004) claimed that collaborative learning increases students' self-esteem, interest in the subject, learning autonomy, and in-depth comprehension of learning tasks. Driver, Squires, Rushworth, and Wood-Robinson (1994) reported that in a group setting students can successfully bring their knowledge and experiences together to advance their thinking. Chang and Mao (1999) reported that while there is no difference in student achievement in knowledge and comprehension parts of a test that incorporated Bloom's taxonomy, the students who worked collaboratively performed better on the application part of the test.

"Warm" model

In contrast to the "cold" nature of Posner's model, the above-mentioned critiques led a "warming trend," to take place in conceptual change research (Sinatra, 2005). Considering the importance of motivational constructs in learning, Sinatra and Pintrich (2003) proposed the term "intentional conceptual change," which was defined as "the goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge" (p. 6). They argued that conceptual change interventions inspired by Posner and his colleagues focused mainly on what teachers could do to manipulate the context to support learners' knowledge restructuring. What is lacking in this model and its related instructional strategies is a description of the role of students' intentions in bringing about change. They criticized that the conceptual change pedagogy was oversimplified as a matter of placing students in circumstances that highlight points of conflict. Dole and Sinatra (1998) pointed out that cognitive conflict is unfortunately often insufficient to induce change. In their Cognitive Reconstruction of Knowledge Model (CRKM), Dole and Sinatra (1998) incorporated motivational constructs into the complexity of conceptual change learning. CRKM describes how learner and message characteristics interact, leading to a degree of engagement with the new concept. The learner characteristics entail existing knowledge and motivational factors. The strength and coherence of a learner's existing knowledge and his or her commitment to it are assumed to influence the likelihood of conceptual change. Motivational factors refer to a learner's interest, emotional involvement, self-efficacy, value, need for cognition, as well as the social context that supports or undermines his or her motivation. Message characteristics refer to the features of the instructional content or persuasive discourse designed to promote conceptual change, which can be described by using adjectives such as comprehensible, coherent, plausible, and rhetorically compelling. It is the interaction of the existing knowledge, instructional message, and individual motivational factors that is assumed to create a space for knowledge reconstruction. Another "warm" model, Cognitive-Affective Model of Conceptual Change (CAMCC) was proposed by Gregoire (2003) based on a study of teachers' resistance to reform-oriented curricula that conflicted with their teaching beliefs. CAMCC shares much similarity with CRKM but posits a greater role for affective constructs such as anxiety and fear in conceptual change. Gregoire claimed that stress and threat appraisals "happen automatically before characteristics of the message are seriously considered" (p. 168). That is, the message characteristics may never be fully processed by a learner if the affective appraisals create a strong tendency to dismiss the message.

In summary, the "cold" model for conceptual change describes conceptual change as a logical process while the "warm" models acknowledge the importance of motivation and belief constructs in this process. In spite of this difference, both cold and warm models share a similar definition of conceptual change: replacement of students' ideas with scientific notions. Vosniadou (1999) moved away from this definition of conceptual change and defined it as a restructuring of a preconception. This amendment, however, still carries an implication that students' less acceptable conceptions are replaced by more sophisticated scientific concepts.

Although various models proposed different ways of teaching for conceptual change, their purpose for so doing remains the same as the cold model: conceptual replacement. Their underlying goal is that science teaching should be an assimilation of students' thinking into Western science-based school curriculum. In other words, these models take Western science as a universal form of knowledge that transcends cultural interpretation and is applicable to every corner of the world (Matthews, 1994). Students' life experiences and ethnoracial backgrounds were largely overlooked when defining the desired achievements of science education.

A CULTURAL PERSPECTIVE OF CONCEPTUAL CHANGE

Multicultural trends in science education

In today's context of globalization, scholars have realized the challenges that student diversity brings to school education. In 2001, two prestigious journals – *Science Education* and *the Journal of Research in Science Teaching* – published special issues to discuss multiculturalism and diversity in science education. According to Carter's (2004) analysis, two main tendencies emerged out of this discussion. The first tendency focused on culturally and linguistically diverse students. This position acknowledges the inherent universalism of Western science, but as it is judged to be the most "powerful" knowledge system, all students, despite their diverse backgrounds, are compelled to accommodate it (Cobern & Loving 2001; Lee, 2001). The remaining task for this group is consequently deemed to develop pedagogical strategies and curricula to facilitate students' accommodation to Western science (e.g., Lee, 2003). The second trend explored a place for non-Western knowledge in school science (Stanley & Brickhouse, 2001). This position identifies the inherent Eurocentricism of current science curriculum and argues for inclusion of indigenous knowledge (Aikenhead, 2001; Snively & Corsiglia, 2001). The problem with this position is the justification for the inclusion of indigenous knowledge in terms of its Western scientific usefulness. It has been assumed that the degree of value depends on its translatability, that is, its removal from the original local, historical, and cultural context for relocation into the mainstream. In other words, most scholars in this group actually reiterate the universal idea of Western science, knowingly or unknowingly. This hidden Eurocentricism is quite obvious when Siegel (2002) tried to convince the readers of the compatibilities between multiculturalism in science education and the universal conception of science. He uses a set of criteria including structural, testable, predictive, and explanatory features to set up the superiority of Western science over local alternatives. He argues that the inclusion of indigenous knowledge in science education "must be justified not in epistemic but in *moral* terms" (emphasis in original, p. 809). Therefore, for both trends mentioned above, the knowledge-power relationships elucidated by postcolonial scholars (Battiste, 2000; Bishop & Glynn, 1999; L. T. Smith, 1999) were used to justify the hidden Eurocentricism, explicitly or implicitly, knowingly or unknowingly.

Carter (2004, 2006) re-read some of this literature from a postcolonial theoretical perspective and criticized the weak arguments of multiculturalism scholars in science education literature. Reiterating the importance of postcolonial science studies (Harding, 1998), Carter (2008a) argues for a more inclusive conceptualization of science. All cultures have systematic attempts to create their own understanding of the universe and their place within it. This more inclusive view sees local knowledge as scientific knowledge, which rises from local contexts and is in response to local needs. "Western science can thus be understood as a particular form of local knowledge tradition, shaped by and reproductive of, the culture and society in which it is articulated" (p. 175).

A hybrid space for science education

It is not new to call the everyday world a culture in contrast to the professional and educational spaces such as the workplace culture, school culture, and so on. According to Geertz (1973), culture is "an ordered system of meanings and symbols, in terms of which social interaction takes place" (p. 5). It consists of norms, values, beliefs, expectations, and conventional actions of a community. In the everyday culture, students' cognition is shaped mainly by their daily communications with their physical and social worlds. For example, the Sun rises in the east and sets down in the west. Such daily observation will make students think the Sun moves around the Earth. "Shut the door. Do not let the cold come in." Such language from parents may well contribute to students' caloric view of heat. The norms and values of these daily communications are much different from those in school communication. They define the unique features of students' everyday cognition, being context-dependent, perception-dominated, interpretation-orientated, and analogy-laden (Zhou, Nocente, & Brouwer, 2008).

For those students with a cultural background different from the white, Western mainstream, their cognition is also shaped by the values, wisdoms, and norms of their ethnoracial culture, called "traditional culture" in this paper. The traditional culture greatly contributes to students' worldviews, which can be very different from science (Gauch, 2009). In my case, the Buddhism culture instilled a view of rebirth, which believes that all persons will be reborn in one of six realms (heaven, human beings, Asura, hungry ghost, animal and hell) after death, based on the Karma they accumulated during their current lives. This life view sustains the concept of ghost in my cognitive schema.

Student preconceptions are a product of their everyday culture plus traditional culture, both of which constitute their life-world culture. If we look at student preconceptions in a different way by changing ourselves from being an outside inspector with scientific ideas as judging criteria to being an insider of students' real-life world, we will find that student preconceptions, although in many cases at odds with science, make sense to students themselves. Students' preconceptions actually have a structure instead of being disconnected (Zhou, Nocente, & Brouwer, 2008). This is why student ideas have been called an alternative framework or science by some scholars (Driver & Erickson, 1983). It is important for us to consider this alternative science as one strong cultural factor when thinking of the goals and approaches of science education.

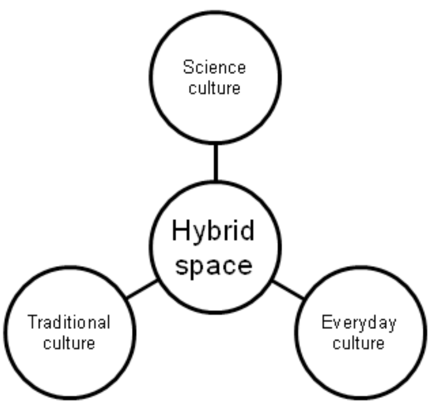

FIGURE 1. *A hybrid space for science education*

In today's context of globalization, science education actually takes place in a hybrid space of these three cultures: everyday culture, traditional culture, and scientific culture (Figure 1). This space should not be seen as static and settled, but should rather be considered as unsettled and dynamic. In regards to literacy development, Sheehy and Leander (2004) claimed that speaking/writing shape the discourse space, and vice versa the space shapes discursive practices. Similarly, these three cultures will interact with each other and provide a unique and dynamic learning space for every science learner.

Many students will experience a clash between their everyday and traditional cultures with scientific culture, which defines the norms and conventions of scientists' thinking and behaving. Costa (1995) and Aikenhead (2001) developed a typology to describe different groups of students based on the congruence level between their non-school cultures and the school culture. These groups of students perform very differently in science learning. The metaphor of border crossing (Giroux, 1992) has been used to illustrate students' cultural transition to school science (Aikenhead, 1996; Aikenhead & Jegede, 1999). This metaphor announces that people must cross borders as they move from one culture to another. It reflects the uneasiness and struggles that students have to face when coming to the science classroom. It also signals that students may have different experiences when they cross the border due to their varying cultural backgrounds and personality factors. Referring to Costa (1995), Aikenhead and Jegede (1999) state that cultural transitions are smooth when the cultures of family and science are congruent, transitions are manageable when the cultures are somewhat different, transitions tend to be hazardous when the cultures are diverse, and transitions are virtually impossible when the cultures are highly discordant. The metaphor of border crossing does provide a tool to discuss the difficulty students have in learning science; however it seems to have little power explaining the phenomena mentioned in the following section.

Co-existence of contradictory conceptions

Postcolonial thinking denounces definitions of cultural superiority. Instead, it includes a concern and respect for the cultures, rights, and interests of all people (Carter, 2008b). Cultural dialogues are suggested as an efficient way to deal with diversity and conflict in many areas including domestic politics, diplomatic relations, and education. The purpose of the dialogue is not to downplay either side, but to generate mutual understanding and reach a win-win solution between multiple parties. In the hybrid space of science education, the result of classroom teaching is likely to be a coexistence of student conceptions and scientific conceptions rather than one replacing the other. Jegede (1995, 1997) noticed the coexistence of traditional culture-related indigenous knowledge and scientific knowledge when he studied science and mathematics education in Africa, and he developed a notion of collateral learning to describe such phenomena. He believed that collateral learning takes place when some learners stored two or more discrepant concepts in long-term memory as cognitive schemata.

My commuting experience between Windsor (Canada) and Detroit (USA) can be used to illustrate this point. Windsor and Detroit are two border cities connected by the Ambassador Bridge over the Detroit River. Windsor is a much smaller city compared to Detroit. I live and work in Windsor, yet I go to Detroit quite frequently for shopping, visiting, and entertainment. I felt very nervous the first time I passed customs at the border. I wondered what questions the custom officers would ask me and worried that I might give inappropriate answers to their questions. However, I now feel much easier crossing the border, although I still carefully answer every question the custom officer asks. The border between the life-world culture and science culture to students is comparable with the Windsor-Detroit border to me. Students may initially feel uneasy in learning science. Although they apparently learn science at school, when they come back to their life-world after school, nobody can be sure they will not slide back to their original thinking. In other words, life-world concepts and science concepts may coexist, and students may find ways to "commute" between these two ways of thinking. Such commuting will become easier as experience accumulates. This coexistence of and commuting between two worlds are quite common in adult life. Many scientists in North America excel in scientific research and teaching, and meanwhile they are faithful Christians (Hutchinson, 2003). In China, many medical doctors integrate Chinese traditional medicine and Western biomedicine in their clinical practice. The ideal of an integrative healthcare system, which combines biomedicine with traditional medicine, has been examined by scholars (e.g. Hollenberg & Muzzin, 2010).

Beyond border-crossing

The coexistence mentioned above, however, is not a simple sum of the original A and B, but a combination of two. My life will be different if I simply stay in Windsor without traveling to Detroit. My perspective of living in Windsor will be different if there was no Detroit close by. Similarly, students' daily thinking will be impacted by school learning. In this sense, even though students did not experience a radical conceptual change, their preconceptions may have been modified by being exposed to scientific views. As far as my concept of ghost is concerned, my initial understanding of ghosts, as described at the beginning of this paper, was developed from what I heard, watched, communicated, and practiced during my childhood life as well as from the Buddhist culture that has been shaping Chinese lives for hundreds of years. School and university education has influenced the way I think and talk about ghosts in an academic context, and I also try to convince myself of the non-existence of ghosts in my life-world contexts using scientific knowledge. However, this does not mean that I have totally forgotten about ghosts. The ongoing negotiation between scientific knowledge and personal knowledge about ghosts has not stopped me from turning back to check whether anything is following me while walking in the dark, but the back turning has become much less frequent compared with my childhood time.

Students' final understanding of the physical world is "in-between" the science culture and life-world culture. In other words, students' exit concepts are neither their orginal preconceptions, nor scientific concepts, rather their preconceptions will have influences on their understanding of science. In this regard, the border crossing analogy has offered little help. Even Aikenhead (2006), a well known scholar in the border crossing literature, has realized that,

> Cross-cultural science teaching can only make indigenous and Western science accessible to students, cognitively, emotionally, and culturally. How students individually integrate the two, if at all, is always their prerogative. Further research on this phenomenon is required. (p. 125)

The metaphor of border crossing implies a static dichotomy between the non-school culture and school culture. It has been found to be inadequate in explaining American Indigenous women's experience in making sense of Eurocentric science in the context of indigenous knowledge (Brandt, 2007, 2008a, 2008b). A different theoretical framework is necessary for an explanation. To this end, Brandt (2007) turns to Hughers' (2002) analytical framework for help, which can be described as *both/and* rather than *either/or* when examining a binary. As I discussed above, the *both/and* cannot be taken as a product of simple mathematical addition, rather a *third entity* or *third space* is necessary to guide our understanding of this topic. The popular thinking of "multiple I" in current cultural studies may offer some insights. As an immigrant from China, if somebody asks me: "Are you a Canadian?" I will answer "yes" since I live and work in Canada with a Canadian passport. However, if he or she asks me: "Are you a Chinese?" I will not answer "no" because I cook Chinese food every day and speak Mandarin with my family members and Chinese friends. This dual, or better still, "mixed" identity defines my overall patterns of values and varying behaviours in different contexts. Similarly, students' thinking will involve some complexity after being exposed to school education. It is this complexity and its formation that is worthy of further study.

THE NEED FOR RE-DEFINING THE GOAL OF SCIENCE EDUCATION

During the days when I was writing the last sections of this paper, I visited my teacher candidates who were placed at schools. After observing every class, I struggled with the same question, "Is it legitimate to *train* students to talk and think as a scientist?" We tell students the accurate definition of scientific concepts and ask them to follow certain steps to solve problems. Although we try different approaches to deliver the content to students and encourage students to learn from mistakes, our final goal is to make sure that students do not make any "mistake." To elaborate this point, I want to share another personal story.

One day while I was at work in Beijing before moving to Canada, my workplace bought every employee a thermal mug. Because fake products were commonly marketed in those days, my colleague and I were interested to know whether our mugs worked properly. My colleague had a Bachelor's degree in science and I then had a Master's degree in science education. We filled the two mugs with hot water and decided to wait about two hours. We thought that a comparison of water temperatures at the end of two hours would provide a good answer to our question. A very scientific process! My brother who visited me from the countryside joined in soon after we filled the mugs with hot water and suggested that we did not have to wait for two hours. He said we could answer the question by simply touching the outside of the mugs: the mug that feels warm from outside does not work! My colleague and I laughed. We laughed at our "perfect" scientific thought and overlooking of such an easy solution suggested by a person without much school education.

Do we "distinguish or extinguish ideas" by teaching for conceptual change? Linn (2008) asked educators. Formal school education seemed to be successful in training my colleague and me to be good science workers. It however subjugated the ideas from us that could easily come out of everyday life experiences.

Science has been traditionally considered as a relatively objective discipline. The goal of science education is accordingly set up as developing students' basic knowledge, skills, and scientific attitude in many countries' curriculum documents with little consideration of what backgrounds or experiences students bring into the classroom. Not very long ago, eradicating "superstitions" was included in Chinese curriculum documents as one of the key goals of science education. However, the ghost story implies that it is almost impossible to completely take away culturally embedded concepts from students. The thermal mug story indicates the negative impacts of traditional science education.

A cultural perspective to science education moves away from a colonial definition of conceptual change as a replacement of student ideas with scientific notions; rather it values the contributions of both knowledges (*plural*) to students' intellectual growth. The cultural perspective takes the classroom as a stage for dialogue. Although scientific epistemology is still one of the significant purposes of science instruction given its great impacts on our lives and society, a discussion of scientific models is dry, biased, and less effective without looking at the differences between the scientific and other ways of knowing. The outcome of classroom discourse cannot be expected to be a replacement of students' views with scientific notions, at least not for all students for all learning tasks. In other words, the goal of science education should not be to force students to throw away their culture-embedded conceptions; rather the coexistence between scientific understanding and culture/experience-based views should be considered as acceptable. Students should not be denounced when they cross the borders of their everyday culture, traditional culture and science culture in two-way directions. In other words, the goal of science education is to have students "master and critique scientific ways of knowing without, in the process, sacrificing their own personally and culturally constructed ways of knowing" (O'Loughlin, 1992, p. 791). Similarly, Hodson (1992) suggested "the task of science teaching is to help all children acquire scientific knowledge, interests, skills, attitudes and ways of thinking without doing violence to their particular cultural beliefs and experiences" (p. 16). In regards to aboriginal education in Canada, Battiste (2000) stated, "Creating a balance between two worldviews [Indigenous and Western] is the great challenge facing modern educators" (p. 202). This statement applies to the education of other ethnoracial groups as well, which is called neo-indigenous thinking by Aikenhead and Ogawa (2007).

ARGUMENT APPROACH TO CONCEPTUAL ADVANCEMENT

In this section, affirming a cultural perspective of conceptual change, I suggest an argumentation approach to teaching scientific concepts. "Argument" has recently appeared in science education literature for its potential function in the social construction of knowledge and in bringing about deeper learning *about* science (Driver, Newton, & Osborne, 2000; Osborne, 2001). Its justifications come from an understanding of the nature of scientists' work. As Kuhn (1993) and Thagard (1992) stated, in the history of science a new framework takes the place of the previous one through scientific argument. For example, the dialogues between the caloric and kinetic views of heat, the particle and wave views of light, and the debate between Bohr and Einstein on quantum mechanics are typical cases in which argument plays a major role. Scientists actually practice argument on a daily basis during the discourse of constructing scientific knowledge that is consistent and acceptable to the scientific community. They argue with themselves through frequent idea changes, and, more importantly, they argue with each other through publication, conferences, and informal occasions in order to build knowledge with minimum bias. It is also believed that science should be taught in a way that reflects the nature of science (American Association for the Advancement of Science, 1990; National Research Council, 1996). From this perspective, the central position of argument in scientific development assures it a space in classroom practice. However, because the underlying goal of science education is still taken as assimilating students into school science, this body of literature (e.g. Osborne, Erduran, & Simon, 2004; Simon, Erduran, & Osborne, 2006) focuses on developing students' skills to construct scientific arguments rather than an appreciation of cultural diversity through argumentation.

Postcolonial thinking actually sees argument as a natural fit for a teaching context where student ideas are in conflict with school science. An argument deals with disagreements. Student preconceptions are in most cases different from scientific notions, and there often exist disagreements among students as well. These differences provide an opportunity for arguments to occur in the classroom. An argument is a recursive journey. It takes time for arguers to understand each other's point and justification. Arguers explain, testify, defend, and convince opponents to accept their ideas while at the same time, they remain open-minded and try to understand the stand of opponents. Different from past conceptual change pedagogy, the argument approach does not endorse a process of letting students choose between "good" and "bad" apples. It instead recommends a process that leads students to examine the pros and cons of both apples for given cultural contexts. Students become intentional learners who actively re-examine their knowledge in a classroom-based social context that is based on the new learning experiences and accepting of the conventions of different cultures (including the Western science culture). The process of conceptual change is, therefore, an argument process of problem solving, with argument and counter argument taking place at each step; but it is not an exercise in downplaying anybody's ideas that were generated from different experiences and cultures. Therefore, a more appropriate name for conceptual change could be "conceptual advancement."

Assume an argument involves an A and B side. From the perspective of side A, the argument has three possible outcomes: (1) Side A agrees with Side B and takes B's stand (accepting B); (2) Side A disagrees with Side B and does not change (rejecting B completely); (3) Both sides reach a mutual understanding and result in a blended solution (rejecting B partially). It is apparent that the past understanding about conceptual change has limited our view to only the first two cases. If students take the scientific view, we feel happy. If students do not, we believe that is because preconceptions are hard to change. We haven't yet thought about the third case enough. The cases where students apparently understood science but reaffirmed back to their original ideas in the daily life context have always been pessimistically reported and attributed to the failure of teaching (Redish & Steinberg, 1999). From a postcolonial perspective, this third case is actually not only possible, but also more likely to take place compared with the other two.

The use of argument in science education can well address the criticisms that Posner et al.'s (1982) model has received since it addresses the social and non-rational factors for learning. As the word argument itself implies, the argument approach of teaching is a social process. Teacher is a facilitator as well as an "arguer" who represents scientific notions. It empowers students to present their ideas and challenge the teacher's stand. Whatever ideas they bring up are significant to the classroom community. The aim of this approach is to help students appreciate, rather than force them to accept scientific views. This process has the potential to make students feel respected and consequently be motivated to get involved. Argument can also effectively incorporate metacognition, which is claimed to be important by Sinatra and Pintrich (2003). Paris and Winograd (1990) stated: “any cognition that one might have relevant to knowledge and thinking might be classified as metacognition” (p. 19). Based on a review of many studies, they concluded that students can enhance their academic learning and cognitive development “by becoming aware of their own thinking as they read, write, and solve problems in school” (p. 15). An argument is a process that can implement the teaching of meta-knowledge. Distinctions and features of students’ life-world thinking and the scientific criteria for knowledge claims will be recognized, discussed, and underlined in the discourse. This kind of meta-knowledge is valuable for students to initiate, coordinate, and control their processes of learning science and to understand issues about science. In other words, students with this knowledge are more likely to become intentional learners (Sinatra & Pintrich, 2003).

In my own school science experience, if my teachers had allowed me to share and discuss with the class, my life-world learning about ghosts and the concept of rebirth, it might not have jeopardized my learning of science at all. Actually, such opportunities would make me feel more comfortable in the science classroom. And more importantly, it might result in even better understanding of both knowledges, their associated epistemologies, and limitations as well.

CONCLUDING REMARKS

Past studies of conceptual change, no matter whether they applied a “cold” model or a “warm” approach, shared the same problem when they portrayed conceptual change as a replacement of student preconceptions with scientific concepts. Cultural studies of science education over the last decades have drawn our attention to many issues such as integration of Indigenous knowledges, inclusion of different worldviews, and school education as cultural transmission. Such postcolonial thinking questions the legitimacy and effectiveness of the colonial process behind the term of conceptual change and advocates a coexistence between the life-world based ideas and Western science-based concepts. In other words, the cultural perspective to conceptual change suggests a rethinking of the goal of science education. The replacement of the life-world cognitive products with the intellectual products of the scientific community is not realistic and justifiable for all students and for all concepts; rather the classroom discourse between the life-world culture and school science culture should aim at students’ enriched understanding of both sides. In the end, students will gain conceptual advancement in their understanding of the discussed topics and issues. It is a pressing task to revisit the curriculum policy documents and change their descriptions of the goal of science education from using assimilation language to more inclusive language.

Since science education takes place in a hybrid space of the everyday culture, traditional culture, and science culture, teaching and learning science in a more authentic way that brings arguments into the classroom has epistemological, pedagogical and moral justifications. Epistemologically speaking, the use of arguments helps students to fully examine both their own ideas and the scientific notions, which will contribute to their in-depth understanding of both epistemologies. Pedagogically speaking, the use of arguments has the potential to motivate students to become engaged in the learning process and provide students opportunities to learn how to respect and be respected in a community. As far as moral considerations, the use of argument can promote cultural appreciation in a diverse student population.

Similar to the promotion of inquiry-based science teaching, school teachers may have concerns with the argument approach. Lack of time, potential risk of losing class control, and possible failure in curriculum content coverage are some of the foreseen issues that may bother teachers when they think of such approach. Also, this approach may pose challenges to those teachers who have inadequate knowledge about cultural perspectives and still believe in teachers' absolute authority inside the classroom. For those teachers who believe in the universalism of science, they might be concerned that this particular argument approach teaches pseudoscientific or supernatural ideas in their science classrooms, resulting in a negative impact on students' understanding of the nature of science. Additional concerns might stem from teachers' lack of preparation in using arguments as a pedagogical means to develop students' in-depth understanding of the epistemologies of Western science and non-Western knowledge. Therefore, for teachers to buy into the argument approach, it is necessary to help teachers change their views about science, philosophy of science teaching, and perception of the power relationship between the teacher and students. This opens up a research agenda for teachers' professional development around this approach of science teaching. As well, future research is necessary to study the actual impacts of argument approach on cultural appreciation among diverse students, the enhancement of student motivation in science classroom, and the advancement of student conceptual understanding.

REFERENCES

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

Aikenhead, G. S. (2001). Integrating western and aboriginal sciences: Cross-cultural science teaching. *Research in Science Education, 31*(3), 337-355.

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. New York: Teachers College Press.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269-287.

Aikenhead, G.S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*, 539-591.

American Association for the Advancement of Science (AAAS). (1990*). Science for all Americans.* NY: Oxford University Press.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Education Psychology*, *84*, 26-271.

Bar, V., Zinn, B., & Rubin, E. (1997). Children's ideas about action at a distance. *International Journal of Science Education, 19*(10), 1137-1157.

Barbosa, R., Jofili, Z., & Watts, M. (2004). Cooperating in constructing knowledge: Case studies from chemistry and citizenship. *International Journal of Science Education*. *26*(8), 935-949.

Battiste, M. (Ed.). (2000). *Reclaiming indigenous voice and vision*. Vancouver, BC: University of British Columbia Press.

Bishop, B. A., & Anderson, C. W. (1990). Student conceptions of natural selection and its role in evolution. *Journal of Research in science Teaching, 27*(5), 415-427.

Bishop, R., & Glynn, T. (1999). *Culture counts: Changing power relations in education*. Palmerston North, NZ: Dunmore Press.

Brandt, C. B. (2007). Epistemology and temporal/spatial orders in science education: A response to Aikenhead & Ogawa's: Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*, 599-605.

Brandt, C. B. (2008a). Discursive geographies in science: Space, identity, and scientific discourse among indigenous women in higher education. *Cultural Studies of Science Education, 3*, 703-730.

Brandt, C. B. (2008b). Scientific discourse in the academy: A case study of an American Indian undergraduate. *Science Education, 92*(5), 825-847.

Carter, L. (2004). Thinking differently about cultural diversity: Using postcolonial theory to (re) read science education. *Science Education, 88*(6), 819-836.

Carter, L. (2006). Postcolonial interventions within science education: Using postcolonial ideas to reconsider cultural diversity scholarship. *Educational Philosophy and Theory, 38*(5), 677-691.

Carter, L. (2008a). Sociocultural influences on science education: Innovation for contemporary times. *Science Education, 92*(1), 165-181.

Carter, L. (2008b). Globalization and science education: The implications of science in the new economy. *Journal of Research in Science Teaching, 45*(5), 617-633.

Chang, C-Y., & Mao, S-L. (1999). The effects on students' cognitive achievement when using the cooperative learning method in earth science classrooms. *School Science and Mathematics, 99*(7), 374-379.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50*(1), 66-71.

Cobern, W. W., & Loving, C. C. (2001). Defining "science" in a multicultural world: Implications for science education. *Science Education, 85*(1), 50 – 67.

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

Dole, J. A., & Sinatra, G. M. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist*, *33*(2/3), 109-128.

Driver, R., & Erickson, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education*, *10*(1), 37-60.

Driver, R., Guesne, E., & Tiberghien, A. (Eds.) (1985). *Children's ideas in science*. Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*, 287-312.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science.* London, UK: Routledge.

Dweck, C. S., & Leggett, E. L. (1988). A social cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256-273.

Gauch, H. G. (2009). Science, worldviews, and education. *Science and Education*, *18*(6/7), 667-695.

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

Georghiades, P. (2000). Beyond conceptual change learning in science education: Focusing on transfer, durability and metacognition. *Educational Research*, *42*(2), 119-139.

Gilbert, J. K., & Watts, D. M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education*, *10*(1), 61-98.

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

Gregoire, M. (2003). Is it a challenge or a threat? A dual-process model of teachers' cognition and appraisal process during conceptual change. *Educational Psychology Review*, *15*(2), 147–179.

Harding, S. (1998). Multiculturalism, postcolonialism, feminism: Do they require new research epistemologies? *Australian Educational Researcher, 25*(1), 37 – 51.

Helm, H. (1980). Misconceptions in physics amongst South African students. *Physics Education*, *15*, 92-105.

Hewson, P. W., & Hewson, M. G. A'B (1988). An appropriate conception of teaching science: A view from studies of science learning. *Science Education*, *72*(5), 597-614.

Hodson, D. (1992). Towards a framework for multicultural education. *Curriculum*, *13*, 15–18.

Hollenberg, D., & Muzzin, L. (2010). Epistemological challenges to integrative health care: An anti-colonial perspective on the combination of biomedicine with complementary/alternative medicine. *Health Sociology Review, 19*(1), 34-56.

Hughes, C. (2002). Beyond the post-structuralist-modern impasse: The woman returner as 'exile' and 'nomad.' *Gender and Education, 14*(4), 411-424.

Hutchinson, I. (2003). Science: Christian and natural. *Perspectives on Science and Christian Faith, 55*(2), 72-79.

Kuhn, D. (1993). Science as argument. *Science Education*, *77*, 319-337.

Kuhn, T. (1970). *The structure of scientific revolutions.* Chicago, Il: Chicago University Press.

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. (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.

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, CA.

Lee, O. (2001). Culture and language in science education: What do we know and what do we need to know? *Journal of Research in Science Teaching, 38*(5), 499 – 501.

Lee, O. (2003). Equity for linguistically and culturally diverse students in science education: A research agenda. *Teachers College Record, 105*(3), 465 – 489.

Linn, M. C. (2008). Teaching for conceptual change: Distinguish or extinguish ideas. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 694-722). New York, NY: Routledge.

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

Matthews, M. (1994). *Science teaching: The role of history and philosophy of science*. New York, NY: Routledge.

McCloskey, M. (1983). Intuitive physics. *Scientific American, 248*, 114-122.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academy Press.

Nolen, S. (1988). Reasons for studying: Motivational orientations and study strategies. *Cognition and Instruction, 5,* 269-287.

Nolen, S. B. (1996). Why study? How reasons for learning influence strategy selection. *Educational Psychology Review, 8*(4), 335-355.

Nussbaum, J., & Novick, S. (1981). Brainstorming in the classroom to invent a model: A case study. *School Science Review, 62*(221), 771-778.

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*(8), 791-820.

Osborne, J. (2001). Promoting argument in the science classroom: A rhetorical perspective. *Canadian Journal of Science, Mathematics and Technology Education*. *1*(3), 271-290.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

Osborn, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland, NZ: Heinemann.

Paris, S. G., & Winograd, P. (1990). How metacognition can promote academic learning and instruction. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 11-52). Hillsdale, NJ: Lawrence Erlbaum Associates.

Piaget, J. (1970). *Genetic epistemology.* New York: Columbia University Press.

Piaget, J. (1973). *To understand is to invent*. New York: Viking Press.

Pintrich, P. R., & De Groot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82,* 33-40.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*(2): 167-99.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Redish, E. F., & Steinberg, R. N. (1999). Teaching physics: Figuring out what works. *Physics Today, 52,* 24-30.

Sheehy, M., & Leander, K. M. (2004). Introduction. In K. M. Leander & M. Sheehy (Eds.), *Spatializing literacy research and practice* (pp. 1-14). New York, NY: Peter Lang.

Siegel, H. (2002). Multiculturalism, universalism, and science education: In search of common ground. *Science Education, 86*, 803-820.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28* (2-3), 235-260.

Sinatra, G. M. (2005). The ''warming trend'' in conceptual change research: The legacy of Paul R. Pintrich. *Educational Psychologist, 40*(2), 107-115.

Sinatra, G. M., & Pintrich, P. R. (2003). The role of intentions in conceptual change learning. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 1-18). Mahwah, NJ: Lawrence Erlbaum.

Smith, E. L., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning in science. *Journal of Research in Science Teaching, 30*(2), 111-126.

Smith, L. T. (1999). *Decolonizing methodologies: Research and indigenous peoples.* London, UK: Zed Books.

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education, 85*(1), 6-34.

Stanley, W. B., & Brickhouse, N. W. (2001). Teaching sciences: The multicultural question revisited. *Science Education, 85*(1), 35-49.

Thagard, P. (1992). *Conceptual revolutions*. Princeton, NJ: Princeton University Press.

Vosniadou, S. (1999). Conceptual change research: State of the art and future directions. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.). *New perspectives on conceptual change* (pp. 3-13). New York, NY: Pergamon Press.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson, B., & Konicek, R. (1990). Teaching for conceptual change: Confronting children's experience. *Phi Delta Kappan, 71*(9), 680-685.

Wentzel, K. R. (1991). Social and academic goals at school: Motivation and achievement in context. In M. L. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achievement* (Vol. 7, pp.185-212). Greenwich, CT: JAI Press.

Zhou, G., Nocente, N., & Brouwer, W. (2008). Understanding student cognition from an analysis of their preconceptions in physics. *Alberta Journal of Educational Research, 54*(1), 14-29.

GEORGE ZHOU is an Associate Professor at the Faculty of Education, University of Windsor. He received his PhD in science education from the University of Alberta and currently teaches undergraduate and graduate courses in science education and research methods. His research areas cover conceptual change, argument, and the use of technology in science teaching. In addition, he conducts research in technology integration with teacher education, and comparative and international education. He can be reached at gzhou@uwindsor.ca.

GEORGE ZHOU est professeur agrégé à la Faculté de l'éducation de l'Université de Windsor. Il a obtenu son doctorat en enseignement des sciences à l'Université de l'Alberta et enseigne présentement des cours portant sur l'enseignement des sciences et les méthodes de recherche aux étudiants de premier et deuxième cycle. Ses domaines de recherche comprennent les changements conceptuels, les débats et l'utilisation de la technologie dans l'enseignement des sciences. Par ailleurs, il dirige des recherches sur l'intégration de la technologie à la formation des enseignants ainsi que sur l'éducation comparée et internationale. Il est possible de communiquer avec lui à gzhou@uwindsor.ca.