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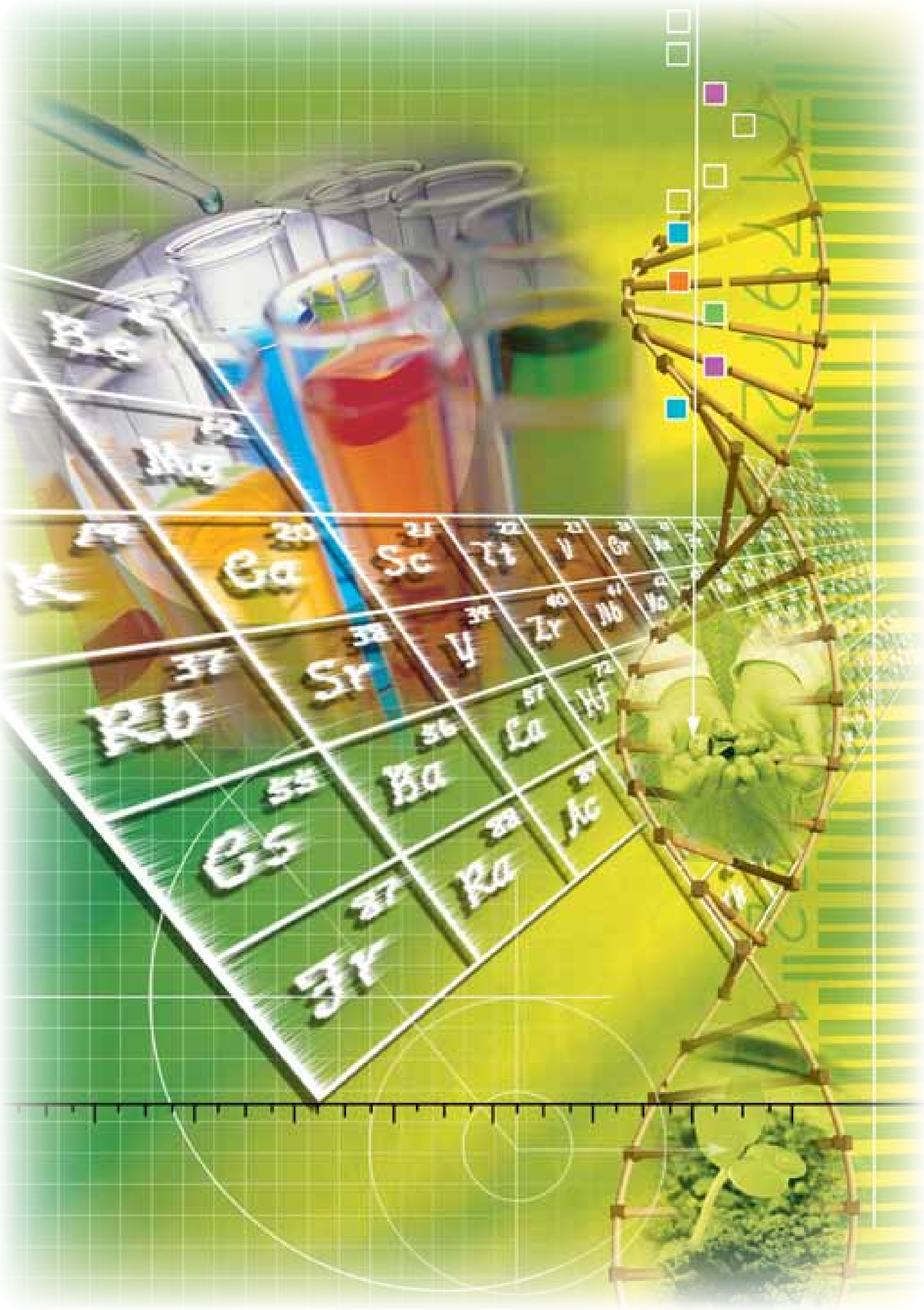

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ASEJ publishes scholarly work and strictly follows the blind review procedures and many other editorial policies described in the *Publication Manual of the American Psychological Association*, 5th edition (Washington, DC: American Psychological Association, 2001). Thus *ASEJ* is a refereed journal similar to most other scholarly periodicals published in Canada and the United States.

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From the Editor

Wytze Brouwer

Joan Chambers, in "Right Time, Wrong Place? Teaching About Climate Change in Alberta Schools," suggests that teaching about climate change in Alberta is limited by a number of factors, including inadequate preparation and curriculum resources. There is a need, in Alberta, to reimagine science and environmental education, since the topic of climate change is of primary importance, perhaps especially for Alberta students.

Stan Bissell, in "The Role of Educators in Increasing Public Certainty in Climate Change Science," looks at ways scientists, the Internet and the mass media can both educate and miseducate students and the public about climate change. Bissell suggests that teachers and educators should develop their interdisciplinary knowledge base so that they can address the issue more authoritatively and help students develop their critical thinking skills so that they, in turn, can evaluate all types of information about climate change more skeptically.

Brian Martin and Peter Mahaffy, in "Using Climate Change to Create Rich Contexts for Physics and Chemistry Education," also recognize the interdisciplinary nature of climate change education and present a number of resources that can help physics, chemistry and general science teachers in Alberta high schools use climate change as a context for learning in many different science topics. The authors outline in detail one program in which they have collaborated—Visualizing and Understanding the Science of Climate Change, which contains nine interactive lessons on climate change.

Leslie Heinsen, in "Why Scientific Literacy Must Be a Focus of Science Education," investigates what it means for today's students to be scientifically literate. Heinsen suggests that focusing on current science, making learning meaningful by engaging the students in dialogue with their peers and addressing socioscientific issues like climate change in class helps make these students ready for critical citizenship.

Monica Chahal, in "Nature of Science or Nature of Reality," investigates what is meant by the nature of science in two settings—the United Kingdom and Alberta. Chahal investigates some of the ways in which the two science curricula succeed or, more often, fail to develop a scientifically literate citizenship.

Mary Anna Pokerznik, in "Usefulness of Nature of Science, Socioscientific Issues and Argumentation in Achieving Scientific Literacy," provides a range of arguments that suggest that a greater focus on the nature of science and the use of student argumentation and discussion on current socioscientific issues, rather than focusing solely on traditional scientific knowledge, will help to develop more scientifically literate students and citizens.

Dawn Wiseman, in "Who Are These Scientist People Anyway? Student Images of Scientists and Ways to Broaden Them," investigates the long-term problem of the image of scientists that is held by students and the general public. Wiseman gives many suggestions about how interacting with scientists or reading about them can broaden people's image of scientists and remove the typical gender-specific image of the white-haired male scientist in his white coat.

Millsap is back. He was a bit reluctant to report on his presentation on "The Psychosexual Equivalent of Heat" to the German Psychological Society, but I finally convinced him that the truth was better than the rumours making the rounds.

Right Time, Wrong Place? Teaching About Climate Change in Alberta Schools

Joan M Chambers

Abstract

The inclusion of socioscientific and environmental issues in the science classroom is an important component of science education, particularly in relation to the goal of helping students become scientifically and ecologically literate citizens. However, including socioscientific and environmental issues, such as climate change, in the high school science curriculum is a complex and problematical undertaking. Curriculum, teacher identity, and underlying sociocultural and ecological contexts dynamically interact to create difficulties for science teachers. Using a phenomenographic research perspective, this study inquires into the challenges of teaching about climate change, by recounting teachers' ways of experiencing climate change education in Alberta science classrooms.

Introduction

Climate change is a contemporary social, scientific and environmental issue considered by most people to be of paramount concern. The inclusion of socioscientific and environmental issues in the science classroom is an important component of science education, particularly in relation to the goal of helping students become scientifically and ecologically literate citizens who are able to fully participate in a democratic, sustainable society (Bingle and Gaskell 1994; Hodson 2003; Kolstø 2001). Tensions arising from epistemological and pedagogical differences (Littledyke 1997; Gough 2002) exist in the relationship between science and environmental education (Ashley 2000; Gough 2002; Hart 2003; Littledyke 2008). However, complex socioscientific and environmental issues, such as climate change, are often excluded from discipline-based science curricula (Gayford 2002) and are, by their complex nature, difficult to integrate into the science classroom (Tytler, Duggan and Gott 2001). Teaching about climate change requires an interdisciplinary approach—it is an integration of scientific, social, economic, political and other nonscientific issues (Gayford 2002; Jenkins 2003; Schreiner, Henriksen and Kirkeby Hansen 2005). Interdisciplinary teaching requires teacher engagement in discourses across subject-specific disciplines; this process can shift teachers away from the comfort and security of their own subject expertise (Lang, Drake and Olson 2006). Additionally, the accountability demands and organization of curricula in secondary schools generally do not support cross-disciplinary teaching of complex, socioscientific and environmental issues (Gayford 2002; Schreiner, Henriksen and Kirkeby Hansen 2005). Adding an environmental dimension to school science also raises questions about the role and teaching of social critique in school science (Hart and Nolan 1999; Jickling 2001).

These varied and complex factors interact in classroom and school to construct a context for teaching about climate change that, in many ways, creates difficulties for science teachers. It is also important to bear in mind that classroom and school are not isolated from community and that community extends from the local to the global. Community provides a context—a setting, a place—that affects teaching and influences the enacted and realized curriculum within the science classroom. The notion of place is intricately linked with curriculum and identity (Chambers 1999; Sumara, Davis and Laidlaw 2001) and is significant when teaching about a socioscientific and environmental issue such as climate change. As Gruenewald (2003) states, "the locus of environmental care may shift depending on one's social and geographical position" (p 6).

This paper inquires into the challenges of teaching about climate change within a context of place—Alberta, Canada. Specifically, I am interested in how teachers experience and engage in climate change discourse in their science classrooms. What challenges or barriers exist for teachers when teaching about a complex environmental issue that requires interdisciplinary teaching approaches? How do context and place shape their practice and interrelate with curriculum? I begin with a brief discussion of the methodological framework I have chosen to conceptualize this research, specifically phenomenography. I then turn to an inquiry into the practice of teaching about climate change and discuss this practice and research in light of context, purposes, and possible insights and implications.

Methodological Framework

Phenomenography

I am interested in teachers' experiences of climate change education. Specifically, I am interested in how Science 10 teachers experience teaching Unit D of the Science 10 curriculum, Energy Flow in Global Systems (Alberta Education 2005). I am investigating the teaching of this unit, which centres on climate change, as a contextualised phenomenon. Consequently, I have turned to phenomenography as a methodology to help me in this enquiry. Phenomenography is a research perspective that stems from the belief that "in order to make sense of how people *handle* problems, situations, the world, we have to understand the way in which they *experience* the problems, situations, the world, that they are handling or in relation to which they are acting" (Marton and Booth 1997, 111). Phenomenography's focus on experience in relation to action in terms of problems, situations or the world around us acknowledges the dynamic processes underlying human meaning making and sociocultural practices. Phenomenography, as a methodology, helps me to uncover the dialectical, complex and contextual factors that interrelate as people describe their experiences and practices in relation to particular phenomena. As described by Marton and Booth (1997), "'a way of experiencing something' is experiencing something *as* something, experiencing meaning that is dialectically intertwined with a structure. 'A way of experiencing something' is a way of discerning something from, and relating it to, a context" (p 112).

Phenomenographic research methods are particularly relevant to educational settings and are appropriate for the study of approaches to learning and, as is the focus of this research, approaches to teaching (Bowden 1994; Marton and Booth 1997). The interview is the most common data collection method in phenomenographic research. Experiences of the participants concerning a particular phenomenon are explored through questioning and conversation. However, while the unit of analysis is the individual interview transcript, phenomenography focuses on the *ways* in which people experience a phenomenon. Consequently, the aim of phenomenographic research is to describe the "*variation* in the ways of experiencing phenomena" (Marton and Booth 1997, 111) and to "explore the range of meanings within a sample group, as a group, not the range of meanings for each individual within the group" (Åkerlind 2005, 323). Because the individual participants are describing the ways in which they experience a common phenomenon, it is assumed that their experiences will be logically related, ordinarily in a hierarchical relationship (Marton and Booth 1997). By piecing together a structure relating the different meanings or ways of experiencing a common phenomenon, the phenomenographic researcher "provides a way of looking at collective experience of phenomena holistically, despite the fact that the same phenomena may be perceived differently by different people under different circumstances" (Åkerlind 2005, 323).

This study was carried out from a phenomenographic research perspective (Marton and Booth 1997) with a focus on searching for variation in teachers' ways of experiencing the teaching of climate change. I conducted semiformal interviews with twelve Science 10 teachers in different areas of the province of Alberta. My intent was to reach teachers who live and work in different places and contexts in Alberta: rural, small urban, large urban; north, south; natural park areas; and different bases of industry/employment. To a large degree, I was able to talk to teachers from each of these different contexts.[1] The interviews or conversations were from 25 to 45 minutes in length and focused on the teachers' experiences of and approaches to teaching the climate change unit of the Alberta Science 10 curriculum. Participating teachers had from 2 to 30 years of teaching experience and included teachers with a BEd with a major in science (physics, biology and general), and teachers with BSc and BEd degrees. One teacher participant has an MSc (physics) and five teachers are currently in the process of completing an MEd. The audiotaped interviews were transcribed and returned to participants to ensure that their thoughts and experiences had been recorded as they intended.

Using a phenomenographic approach, the analysis of the interview data began with an initial categorization of the ways in which each individual teacher described his or her experiences of teaching about climate change. However, the focus of analysis then shifted to a collective approach, examining the variations in the ways teachers, as a group, experienced teaching about climate change. As these various ways of experiencing, or categories of description (Marton and Booth 1997), emerged, a hierarchical, relational structure, or *outcome space* (Marton and Booth 1997), linking these categories of description became apparent. The emergent outcome space is necessarily complex; while I am treating the teaching of climate change in Science 10 as a singular phenomenon, in reality this is a complex, interrelated, contextual and oftentimes difficult process and practice. As I enquire into this practice and its contexts, purposes and implications, I will describe the emergent outcome space and illustrate the relational structure of the teachers' experiences.

Inquiry into Practice

Contexts

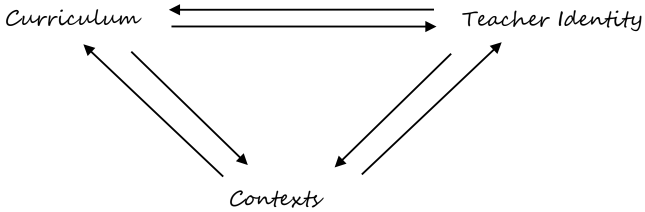
Teaching, learning and being in a place constructs a particular context for the practice of science and environmental education. Alberta is a province of incredible natural beauty and diverse landscapes (Downing and Pettapiece 2006); a province that has experienced incredible economic growth due primarily to the oil and gas industry, especially oil sands development (Laird 2005); a province that has been politically governed over the past 40 years by the right-leaning Conservative Party guided by neo-liberal policies (Harrison 2005); a province that produces the highest amount of greenhouse gases in Canada, due primarily to the production and transportation of fossil fuels (Environment Canada 2006). It is a place—a context—with both advantages and challenges. It is within this context and ecosocial dynamic that Grade 10 science teachers are asked to integrate environmental education into the subject area of science and teach about climate change. Through the context of climate change education, it is expected that students will develop an understanding of the "social and environmental contexts of science and technology" (Alberta Education 2005, 4). But how is that understanding mediated by the cultural, political, economic and ecological contexts that influence curriculum? How does this place intersect with pedagogical practices?

Education in Canada is a provincial jurisdiction; each province prescribes a mandated provincial or provincewide curriculum. Environmental education in Alberta is not taught as a discrete subject but, as is not uncommon, is subsumed primarily within science education (Simmons 1989). A brief overview of the structure of the Alberta high school (Grades 10 to 12) science curriculum shows that science education is principally centred on the three basic science disciplines: physics, chemistry and biology. Students in the academic stream take a common general science course, Science 10, and then take their choice of the 20- and 30-level discipline courses (ie, Physics 20/30, Chemistry 20/30 and Biology 20/30). Alberta Education also offers a general science 20-and 30-level curriculum, but this curriculum is not offered at many high schools, especially schools with a small student population, nor, overall, do many students enrol in these courses.[2] All core 30-level subject areas in Alberta are assessed, in part (50 per cent of the student's final grade), through provincewide diploma examinations. Science 10 is divided into four topic areas or units, each assigned 25 per cent of curricular time by Alberta Education (2005): Unit A: Energy and Matter in Chemical Change (chemistry), Unit B: Energy Flow in Technological Systems (physics), Unit C: Cycling of Matter in Living Systems (biology) and Unit D: Energy Flow in Global Systems (climate change). Each of the four units focuses on a specific Science, Technology and Society (STS) curricular emphasis: Units A and C focus on the nature of science, Unit B on science and technology, and Unit D on social and environmental contexts. Consequently, while there are a few environmental outcomes in the other units, the curricular space for environmental education in Science 10 is primarily in the climate change unit. But, in speaking with teachers, this last unit is either considerably shortened or, in some instances, not taught at all. Why? What are the barriers that teachers experience concerning this particular topic? What role do contexts—cultural, political, economic and ecological—play in enacting or shaping those barriers and the teaching of climate change? Let me now turn to my analysis of the interview transcripts in order to elucidate the barriers teachers experience that emerged from the data and describe how the underlying contexts affect environmental science education practices in Alberta.

Practices and Purposes

An important element of phenomenographic research is the outcome space (Marton and Booth 1997). The outcome space describes, holistically, a relational portrayal of the various categories of description, or ways of experience, that emerge from the data analysis. As the Science 10 teachers described their practices and experiences of teaching the curricular climate change topic, a complex and interrelated structure began to emerge. As I spoke with the teachers about their experiences, ideas about curriculum and teacher identity emerged. I also began to see the strong influence of underlying contexts acting to shape these experiences. Figure 1 depicts a simplified view of the emergent outcome space. Not included in this discussion (or depicted in Figure 1) is student identity. I recognize that students and their contextual spaces are integral to the teaching and learning experience; however, my focus for this paper is on teachers' experiences and the underlying contexts that influence practice. Ordinarily, the outcome space is hierarchically structured; however, a dialogical relationship emerged through the analysis of the interview data. Consequently, I chose to place contexts underneath curriculum and teacher identity in the figure because contexts often go unrecognized or are more implicit than explicit. Though difficult to tease apart due to the complex and dialogical nature of educational practice, I begin my exploration of the outcome space and Science 10 teachers' environmental education practices and the barriers they experience with curriculum, followed by teacher identity. In each case, I address how the underlying contexts affect their practices and experiences.

Figure 1: Outcome space—interrelated categories of description



Curriculum

School curriculum is mediated by social and political factors—it is constructed by curriculum developers who bring their own socially mediated values and beliefs to the curriculum development process. As a consequence, curriculum is neither neutral nor value free (Hildebrand 2007). The provincially mandated science curriculum is not simply a document, a program of studies, that teachers enact in their classrooms. Rather, the curricular process is dynamic, complex and dialogical; it is affected by and embedded in social and political contexts. How do these underlying contexts affect curriculum and the participant teachers' experiences of enacting climate change education?

With the exception of only a single teacher, every teacher experienced *time*, or the perception of a lack of time, as the primary barrier affecting their enacted curriculum and the inclusion of climate change education in a manner that they felt did the topic justice. They believed that the Science 10 curriculum content—the intended curriculum—is too heavy. Though each of the teachers I spoke with expressed the belief that environmental education in general and climate change education specifically are very important, they felt that it is more imperative that students get the necessary biology, chemistry and physics concepts they will need in order to be successful in Grade 11 science courses and, in turn, Grade 12 diploma-level courses. The following quote from one teacher exemplifies a common view held by many of the teachers I interviewed:

> Time is the number one factor. … Because students move on in biology, chemistry, or physics, … we feel obligated to teach biology, chemistry, physics well and get those foundations well laid. The content in each of those units is expansive. It's excessive, I think, for what the students are capable of processing, and for what they need to carry over to the next year. However, it is still in the curriculum, so climate sort of gets pushed last because they're never going to be tested on climate again. (Teacher A)

In general, the teachers gave priority to the discipline sciences, not only for preparation for the 20-level courses, but also for the 30-level diploma examinations. When asked if they felt the weight of accountability even in Grade 10 (when diploma exams are still two years off), most teachers replied "yes." This pressure that teachers felt reflects the political and social contexts that emphasize standards and achievement testing (McEwen 1995; Wideen et al 1997). As a result, climate change education specifically and environmental education in general are not given full consideration in Alberta high school science instruction. The teachers I spoke with expressed regret at not being able to spend more time on the topic—they placed a high value on climate change education and on including environmental issues in their science teaching[3]—but they felt the mandated curriculum left them little choice. This is not a comfortable position for teachers to be in—essentially at cross-purposes with their own values and educational beliefs. I think this sense of feeling at odds with the mandated curriculum and personal values comes across in this teacher's comment:

> It's a very important topic and really deserves the time and energy to make it a good topic for students to learn, to make it meaningful, to make it relevant. … The importance is certainly there. It really does merit the time and energy. It's unfortunate that it is also the topic that is ditched when, you know, June rolls along and we're still trying to bumble through the last of biology, chemistry or physics. (Teacher A)

The hurried teaching of the climate change unit also has other curricular consequences; this practice constructs both hidden and null curricula. The hidden curriculum—unintended, unplanned outcomes—emerges as teachers place greater emphasis on the basic science disciplines and less emphasis on climate change and environmental issues. The students pick up messages about what is valued or not—that is, concern about our changing climate. The underlying social and political context in Alberta, a province whose government did not support Canada's ratification of the Kyoto Protocol, supports this perception.

The null curriculum is a consequence of what is neglected, systematically omitted, or not taught or considered (Hildebrand 2007). Because teachers devote less time to the climate change unit, they necessarily make decisions about which curricular outcomes to teach and which to omit. The teachers I spoke with tend to focus on curriculum outcomes and concepts that either tie into the other Science 10 units and/or the 20-level courses or on concepts they feel do not require as much time to develop; that is, they tend to stay away from the issues and decision-making objectives as these are time consuming (and perhaps more uncomfortable) to address. The lack of time allowed for student decision making and action is regrettable, because this disempowers students and leads them to believe that what they do will not make a difference (Jenkins 2002). Hildebrand (2007) suggests that "the manner in which the intended curriculum is enacted in real-time gives clear messages to students about what the teacher values, and is read as representative of science" (p 47). And, because environmental education in Alberta is predominantly embedded in science instruction, the consequent realized curriculum—the messages the students may pick up—devalues environmental care and consciousness.

The interdisciplinary nature of science and environmental education constructs a second, though less acknowledged, barrier for teachers. Through conversation with the Science 10 teachers about their teaching experiences, the interdisciplinary nature of the climate change topic emerged as a difficulty for many of them. The science of climate change is complex and interdisciplinary, drawing as it does from the biological, chemical, physical and earth sciences as well as mathematics and computer sciences (McBean and Hengeveld 2000). But the subject of climate change is not solely scientific—it is a socioscientific issue; that is, it blends science and social concerns. Political, economic and societal factors are important in understanding the global issue of climate change. The difficulty teachers experience with the interdisciplinarity of climate change education is twofold: (1) secondary science teachers in Alberta are discipline specialists; and (2) high school classes are segregated into the distinct subject areas. The teachers I spoke with are not entirely comfortable with the science of climate change; most teachers expressed concern about their content knowledge of at least one of the disciplines (eg, physics or biology), and several commented on their lack of education in the earth and atmospheric sciences. The crossover into the social arena and the concomitant uncertainty also cause difficulty for science teachers (Kim and Fortner 2006). Some felt unprepared for or uncomfortable with this crossover, while others believed their responsibility was to focus their instruction on the science of climate change. Questions emerge about the role of science teachers and science education and the place of environmental literacy and citizenship—if not in science classes, where do they fit in the Alberta curriculum? Social studies seems an obvious choice, but the segregation of high school classes into distinct subject areas makes the necessary integration of the science and social aspects of climate change education difficult. Time (or rather the perception of a lack of time due to curriculum content demands), subject division and specialization, accountability—these and other political and socially contextual curricular decisions interact to affect teachers and the teaching of climate change. I now turn to teacher identity to explore how the teachers' stories and personal contexts, including place, interact and affect the teaching of climate change in their science classrooms.

Teacher Identity

The teachers I spoke with come from varied backgrounds and places. Some are very experienced teachers and some relatively new. Some teachers work in large urban high schools, others in small, semirural schools. All hold personal values and beliefs regarding environmental stewardship, climate change, and environmental and science education. All have their own stories to tell about their experiences teaching Science 10, but their stories often contain similar threads.

Teachers in semirural schools seem, in some ways, to be in an enviable position, and yet in other ways their situations are more difficult than those of their urban counterparts. Because of small school size, teachers in semirural schools are not as defined or constricted by their subject area. In many cases, the Science 10 teacher *is* the science department; the school may have only one Science 10 class. As a consequence, these teachers are able to massage class schedules in order to work collaboratively with, for example, the social studies teacher. The teachers in large urban high schools find scheduling highly problematic for cross-disciplinary teaching.

In my conversations with teachers in the smaller centres, place seemed to play a larger or more explicit role in their teaching practice. These teachers were more aware of underlying sociocultural and ecological contexts than their urban colleagues, recognizing the influence of place in their teaching. Alberta is primarily a natural resources-based economy, a fact that is experienced more strongly in the smaller centres. For example, "90 per cent of our economy in [our community] is oil driven, and so you have to be aware that you're going to get some resistance when you talk about use of resources and things like that as driving climate change," (Teacher B) and "Since we are either forestry or oil based or farming out where I am, that definitely makes it [climate change] a bit of a touchy subject" (Teacher C). One teacher I spoke with has taught in both a small, resource-based centre and a large urban city; he commented on the differences between the two experiences, indicating that teaching in the city presented less "hassle." He had this to say about his experience in the small centre, "I taught in … a very resource-based town. A little bit of oil and gas but mostly mining and the minerals. So anytime you brought up an environmental issue, oh, you'd have to tread very carefully because as a science teacher, you were one of the few opposing voices" (Teacher D). Though the mandated curriculum is intended to be the same across the province, the place where a teacher finds him- or herself working and living affects the enacted curriculum and may conflict with his or her personal values and identity as a teacher; the curricular influences of the underlying social, political and economic contexts are evident.

Earlier I indicated that all but one of the teachers talked about time as a problem; the teachers stated that a shortage of time, as a consequence of an overloaded curriculum, was the primary barrier to teaching the climate change unit and enacting the curriculum as intended. They felt that it was necessary to spend more time on the biology, chemistry and physics units in order to better prepare students for the 20-level courses and, eventually, the 30-level diploma examinations. These are very real pressures that teachers experience but, ultimately, the teachers are responsible for many of these curricular decisions and choices. I believe their identity as secondary science specialist teachers is a significant factor. Interestingly, only one of the twelve teachers interviewed (Teacher D) did not suggest time as a barrier. I was surprised that he did not mention it, so I pointedly asked him if he thought time was a concern or challenge. While he recognized that "it happens," he ascribed the issue of time to essentially two factors: teacher identity and the consequent curricular decisions, and a misinterpretation or lack of attention to the program of studies (the mandated curriculum). He viewed the latter as "teaching the textbook rather than the program of studies"—going beyond what the mandated curriculum actually requires and struggling with a perceived overloaded curriculum as a consequence. He also spoke of teacher identity:

> In a high school, we as science teachers usually think of ourselves in terms of a discipline. I'm a

> physics teacher, I'm a chemistry teacher, I'm a biology teacher. … Teachers are going to have a subject area they enjoy more. That's probably one of the reasons why they went into teaching science in the first place. So what do they do? I'm a chemistry teacher, so I'm really going to teach chemistry. So they creep into the Chem 20 part of the program of studies. They don't just limit it to Science 10. And the physics teacher probably does something similar, and the biology teacher does something similar. Well, if you keep adding more to your favourite curricular area, you're going to run out of time.

The implications of teacher identity and subject/discipline specialization go beyond preference for teaching the "favourite curricular area." The curricular decisions that Science 10 teachers make—because of their identity, external pressures and directives, and underlying contexts—greatly affect students' education about climate change, potentially influencing the development of their environmental consciousness.

Curriculum, teacher identity and contexts are intricately interwoven and cannot easily be teased apart. Underlying sociocultural and ecological contexts, often unacknowledged, play a significant role in shaping science and environmental education practices. Recounting teachers' ways of experiencing climate change education in Alberta Science 10 classrooms offers insights and suggests implications for practice and meeting the challenges of including socioscientific and environmental issues in science education.

Insights and Implications

Many of the concerns the teachers raised during our conversations about climate change education are not new. For example, Ratcliffe and Grace (2003) note similar challenges or reasons why science teachers have difficulty including socioscientific and environmental issues in their science teaching (p 37). The story seemingly remains the same (cf Bybee 1991). Perhaps it is time to rewrite the story is rewritten and reimagine science and environmental education.

The mandated Science 10 curriculum in Alberta does include space for environmental education practices, especially within the climate change unit. However, the reality of the enacted curriculum narrows and transforms these practices. Furthermore, the realized or learned curriculum may be very different from what is intended due to the hidden and null curricula that speak volumes to students about the importance of climate change and environmental thought and action. The subject specialization of high school teachers and the further delineation of science teachers into their disciplines have curricular consequences. Alberta science teachers are asked to teach environmental education embedded in their science instruction but get little preparation or teacher education support. Many teachers, including the teachers I spoke with, value the inclusion of environmental issues in their science teaching. However, attitude is not enough; high school science teachers are hampered by a limited background in environmental education (Kim and Fortner 2006). Furthermore, science teachers may not have the necessary pedagogical skills for interdisciplinary or cross-disciplinary teaching or the confidence to include socioscientific and environmental issues (Lang, Drake and Olson 2006; Ratcliffe and Grace 2003).

The teachers in this study recognized the problematical nature of the climate change unit and the challenges they face in including environmental outcomes in their science teaching. They offered some possible new directions for practice, including making space in the Alberta high school curriculum for an environmental studies course or drawing on climate change as an integrative theme for the whole of Science 10. Though the teachers are aware of both the benefits and difficulties inherent in inter- and cross-disciplinary teaching, they did not question the structure of high school science—its segregation into the different disciplines and isolation from other subject areas. Aoki (1993) calls upon educators to problematize the traditional topography of curriculum, that is, familiar categories of *science*, *geography* and *literature*, in order to question how science and the humanities should be allowed to coexist. But to do so also asks high school teachers to question their identity as specialist teachers, a difficult undertaking. Also difficult, but equally important, teachers must critically examine the underlying sociocultural and ecological contexts that influence curriculum. They need to pay particular attention to the place where they teach and how their science and environmental education practice is shaped by this context.

If, as educators, we believe that the inclusion of socioscientific and environmental issues in the science classroom is important, particularly in relation to the goal of helping students become scientifically and ecologically literate citizens, it is crucial that we find a way to rewrite the story. Climate change education is too important to continue to marginalize. Teachers, teacher educators and curriculum developers need to reimagine science and environmental education because, as one teacher stated, "It's a very important topic and really deserves the time and energy to make it a good topic for students to learn, to make it meaningful, to make it relevant. … The importance is certainly there" (Teacher A).

Acknowledgements

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Notes

1. Unfortunately, I was not able to speak with any teachers in the region of the province most involved in oil sands mining and development; I was denied approval by the school board—perhaps telling in and of itself. Also, though I was given district approval, I did not have any teachers from the natural parks areas volunteer to participate in this study.

2. In the 2006/07 school year, the total number of students provincewide who wrote the Biology 30, Chemistry 30 and Physics 30 diploma examinations was 50,186, compared with 3,603 who wrote the Science 30 diploma examination (Alberta Education 2007).

3. I recognize that the teachers who agreed to participate in this study likely did so because they have an interest in or place a value upon climate change education and/or the environment.

References

Åkerlind, G S. 2005. "Variation and Commonality in Phenomenographic Research Methods." *Higher Education Research and Development* 24, no 4: 321–34.

Alberta Education. 2005. *Science 10*. Available at http://education.alberta.ca/media/654833/science10.pdf (accessed November 21, 2011).

———. 2007. Biology 30 Five-Year Diploma Examination Results. Available at http://education.alberta.ca/media/735785/table.pdf (accessed November 21, 2011).

Aoki, T T. 1993. "Legitimating Lived Curriculum: Towards a Curricular Landscape of Multiplicity." *Journal of Curriculum and Supervision* 8, no 3: 255–68.

Ashley, M. 2000. "Science: An Unreliable Friend to Environmental Education?" *Environmental Education Research* 6, no 3: 269–80.

Bingle, W, and J Gaskell. 1994. "Scientific Literacy for Decision Making and the Social Construction of Knowledge." *Science Education* 78, no 2: 185–201.

Bowden, J A. 1994. "The Nature of Phenomenographic Research." In *Phenomenographic Research: Variations in Method*, ed J A Bowden and E Walsh. Melbourne, Australia: Royal Melbourne Institute of Technology.

Bybee, R W. 1991. "Science-Technology-Society in Science Curriculum: The Policy-Practice Gap." *Theory into Practice* 30, no 4: 294–302.

Chambers, C. 1999. "A Topography for Canadian Curriculum Theory." *Canadian Journal of Education* 24, no 2: 137–50.

Downing, D J, and W W Pettapiece. 2006. Natural Regions and Subregions of Alberta. Edmonton, Alta: Government of Alberta, Natural Regions Committee.

Environment Canada. 2006. *National Inventory Report, 1990–2006. Greenhouse Gas Sources and Sinks in Canada—A Summary of Trends*. Available at www.ec.gc.ca/pdb/ghg/inventory_report/2006/som-sum_eng.pdf (accessed July 17, 2008).

Gayford, C. 2002. "Controversial Environmental Issues: A Case Study for the Professional Development of Science Teachers." *International Journal of Science Education* 24, no 11: 1191–1200.

Gough, N. 2002. "Moral Outrage in Education." *Science Education* 86, no 4: 596–99.

Gruenewald, D A. 2003. "The Best of Both Worlds: A Critical Pedagogy of Place." *Educational Researcher* 32, no 4: 3–12.

Harrison, T W. 2005. Introduction to *The Return of the Trojan Horse: Alberta and the New World (Dis)Order*, ed T W Harrison. Montreal: Black Rose Books.

Hart, P. 2003. *Teachers' Thinking in Environmental Education: Consciousness and Responsibility*. New York: Peter Lang.

Hart, P, and K Nolan. 1999. "A Critical Analysis of Research in Environmental Education." *Studies in Science Education* 34: 1–69.

Hildebrand, G M. 2007. "Diversity, Values and the Science Curriculum." In *The Re-Emergence of Values in Science Education*, ed D Corrigan, J Dillon and R Gunstone, 45–60. Rotterdam: Sense Publishers.

Hodson, D. (2003). "Time for Action: Science Education for an Alternative Future." *International Journal of Science Education* 25, no 6: 645–70.

Jenkins, E W. 2002. "Linking School Science Education with Action." In *Science Education as/for Sociopolitical Action*, ed W-M Roth and J Désautels. New York: Peter Lang.

———. 2003. "Environmental Education and the Public Understanding of Science." *Frontiers in Ecology and the Environment* 1, no 8: 437–43.

Jickling, B. 2001. "Environmental Thought, the Language of Sustainability, and Digital Watches." *Environmental Education Research* 7, no 2: 167–80.

Kim, C, and R W Fortner. 2006. "Issue-Specific Barriers to Addressing Environmental Issues in the Classroom: An Exploratory Study." *Journal of Environmental Education* 37, no 3: 15–22.

Kolstø, S D. 2001. "Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues." *Science Education* 85, no 3: 291–310.

Laird, G. 2005. "Spent Energy: Re-Fueling the Alberta Advantage." In *The Return of the Trojan Horse: Alberta and the New World (Dis)Order*, ed T W Harrison. Montreal: Black Rose Books.

Lang, M, S Drake and J Olson. 2006. "Discourse and the New Didactics of Scientific Literacy." *Journal of Curriculum Studies* 38, no 2: 177–88.

Littledyke, M. 1997. "Science Education for Environmental Education? Primary Teacher Perspectives and Practices." *British Educational Research Journal* 23, no 5: 641–59.

———. 2008 "Science and Environmental Education: Approaches to Integrating Cognitive and Affective Domains." *Environmental Education Research* 14, no 1: 1–17.

Marton, F, and S Booth. 1997. "The Idea of Phenomenography." In *Learning and Awareness*, 110–36. Mahwah, NJ: Lawrence Erlbaum.

McBean, G A, and H C Hengeveld. 2000. "Communicating the Science of Climate Change: A Mutual Challenge for Scientists and Educators." *Canadian Journal of Environmental Education* 5, no 1: 9–23.

McEwen, N. 1995. "Educational Accountability in Alberta." *Canadian Journal of Education* 20, no 1: 27–44.

Ratcliffe, M, and M Grace. 2003. *Science Education for Citizenship: Teaching Socio-Scientific Issues*. Philadelphia: Open University Press.

Schreiner, C, E K Henriksen and P J Kirkeby Hansen. 2005. "Climate Education: Empowering Today's Youth to Meet Tomorrow's Challenges." *Studies in Science Education* 41, no 1: 3–49.

Simmons, D A. 1989. "More Infusion Confusion: A Look at Environmental Education Curriculum Materials." *Journal of Environmental Education* 20, no 4: 15–18.

Sumara, D, B Davis and L Laidlaw. 2001. "Canadian Identity and Curriculum Theory: An Ecological, Postmodern Perspective." *Canadian Journal of Education* 26, no 2: 144–63.

Tytler, R, S Duggan and R Gott. 2001. "Dimensions of Evidence, the Public Understanding of Science and Science Education." *International Journal of Science Education* 23, no 8: 815–32.

Wideen, M F, T O'Shea, I Pye and G Ivany. 1997. "High-Stakes Testing and the Teaching of Science." *Canadian Journal of Education* 22, no 4: 428–44.

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The Role of Educators in Increasing Public Certainty in Climate Change Science

Stan Bissell

The consensus among climate scientists is that the Earth is currently undergoing a warming trend and that anthropogenic activity is contributing to this warming. Results from thousands of peer-reviewed research studies have continued to support the conclusion that human activity is affecting the climate (McBean and Hengeveld 2000, 10). Many scientists and environmental groups have attempted to convey that the effects of climate change are real and serious, and that this issue needs the immediate attention of the public and policy makers. In spite of these efforts, there is public confusion, mistrust and general apathy about climate change. The widespread lack of public engagement on this issue is due in large part to the mass media's approach to reporting science issues. Because mass media has contributed to an erosion of the public's trust in climate change science, journalists, scientists and science educators must work toward re-establishing this trust. It is important to include students as part of the public when focusing on climate change education, not just because they should be informed when they eventually become voting citizens and decision makers, but because they already possess the ability to take personal action on climate change and to inform and influence the decisions of adult members of the public. This paper will focus on the role that science educators have in the context of managing, interpreting and teaching climate change science.

The public obtains information about science, including climate change science, from four primary sources: scientists, the Internet, mass media, and educators.

Scientists

General agreement by climate scientists on the realities and causes of climate change has not been enough to sway public opinion and promote consensus on what, if any, action needs to be taken on this issue. Scientists do not typically communicate directly with the public because they are not trained to do so (McBean and Hengeveld 2000, 20), are not willing to do so (Elam 2004, 230; Weigold 2001, 173) or are blocked from doing so (Zivkovic 2010). Elam asserts that many scientists perceive science communication as a distraction, a pursuit of retired or less-talented scientists, and an obligation that comes third after their more important jobs of doing research and teaching (p 230). Although this view of the importance of science communication is changing, many scientists still see any popularization of science as a threat to the validity of science. Weigold (2001) describes the opinions of some scientists on communicating with the public:

> Fellow scientists may look down on colleagues who go public, believing that science is best shared through peer-reviewed publications. Scientists may also believe that broadcast media are trivial, that scientists should be dedicated to their work, that scientists should have neither the time nor inclination to blow their own trumpets, that the rewards of a media career can compromise a scientist's integrity, that the public may commandeer a story and distort it, and finally that the public may get excited about the wrong side of the story. (p 173)

Bora Zivkovic is the editor of *Scientific American*'s blog network; in a 2010 posting to his blog, *A Blog Around the Clock*, he argues that scientists are not poor communicators, but rather that they do not have access to communicate on their own terms: "scientists communicate all the time, and do it well, but only to the already receptive audience which actively seeks them" (para 5). Scientists, unable or unwilling to communicate with the public, must rely largely on mass media to communicate with the public for them. Unfortunately, the message is often lost or misinterpreted as it gets simplified by mass media. When scientists allow others to communicate for them, messages about science can become confused by the politics and/or the celebrity of the messenger. For example, the highly successful climate change documentary film, *An Inconvenient Truth* (2006), presented by Al Gore—a nonscientist—helped increase public awareness of the issue of climate change. However, to some extent, the message Gore presented was likely perceived as biased by some because of his political background. In the opening minutes of *An Inconvenient Truth*, Gore introduces himself by saying "I'm Al Gore. I used to be the next president of the United States," referencing the 2000 presidential election that he closely lost. In this influential documentary, the politics of the speaker are intertwined with the science of climate change; this might create the impression that there is an agenda behind the science presented.

The public can also misinterpret or misunderstand science because of the way that scientific findings are vetted and presented, thus increasing the public's uncertainty in these findings. The peer-review process is an important part of scientific inquiry, and the scientific community feels that having colleagues criticize and debate the work of scientists is required in order to maintain high standards and improve the performance of individuals and institutions. However, this adversarial process of peer review can be misinterpreted by the public and the media; the nature of scientific debate can be viewed, and skewed, as scientific doubt; this can hinder the urgent message of climate scientists from getting to the public. Corbett and Durfee (2004) explain this issue by stating that "when scientists acknowledge that they do not know *everything* (ie, that uncertainties remain), there is an unfortunate tendency of both media and the public to interpret this as not knowing *anything* about the subject" (p 143) (italics in original). Scientists are often able only to use correlations to make their conclusions, rather than prove cause and effect; this results in the presentation of findings that use softer language such as "linked to" or "related to" to qualify the findings. These tentative statements are viewed as more accurate by the scientific community, but the public can easily misinterpret this language as uncertainty. McBean and Hengeveld (2000) argue that scientists could make climate change messages clearer and more effective by focusing on communicating the points that they can agree upon and presenting the points of disagreement in a nonadversarial way (p 18).

The Internet

Digital information on the Internet makes the science and nonscience of climate change more current and accessible to interested members of the public who seek information on the issue. Research institutions have websites with valuable data on climate change, and climate change scientists are able to communicate with the public directly through their professional websites, blogs, podcasts, YouTube videos and social media such as Twitter. The Internet does not just increase the ability of scientists to reach out to the public—it also allows the public to directly reach out to scientists. Zivkovic (2010) argues that the traditional one-to-many form of public communication that has been employed by most scientists—where expert scientists communicate to passive lay audiences—is outdated and no longer accepted by a public who are now used to instant access to information through their computers and hand-held wireless devices. In the current age of social media, the public now expects to be engaged in both immediate and two-way communication. Scientists may find that an additional benefit of using digital publications, websites and blogs is that the Internet frees scientists of the space and time constraints that exist in traditional print media and peer-reviewed journals. Different genres on the Web allow the inclusion of the context and background needed to understand an issue. For example, the website *RealClimate: Climate Science from Climate Scientists* (www.realclimate.org) is a moderated forum for scientists to directly communicate their work to the public and to comment on climate change developments.

> RealClimate is a commentary site on climate science by working climate scientists for the interested public and journalists. We aim to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary. The discussion here is restricted to scientific topics and will not get involved in any political or economic implications of the science. (www.realclimate.org, About, para 1).

Although I have argued that the public's perception of scientists' peer-review process creates a communication challenge, the Internet also presents a challenge for the opposite reason: much of the information about climate change available on the Internet is not reviewed at all. Persons who disagree with the opinions of the majority of climate change scientists, called contrarians, easily make use of the multipurpose genres on the Internet to present misinformation and their extreme views. These contrarians range from complete skeptics who deny that climate change is occurring to doomsayers who use climate change to present a catastrophic or apocalyptic future. Many contrarian websites appear professional and credible. For example, the Friends of Science website (www.friendsofscience.org) uses unreferenced yet scientific-looking graphs and charts to back up their skeptical claims that the Sun is the direct and only cause of climate change. Their website even presents a scientific advisory board with the names of three credible-sounding scientists.

The Internet provides an easy medium for well-funded interest groups to disseminate misinformation about climate change and reduce public trust in climate change scientists. Corbett and Durfee (2004) describe how Ross Gelbspan, in his 1998 book *The Heat Is On*, exposed how fossil fuel companies and conservative politicians engaged in the purposeful manufacture of doubt to undermine the science of climate change (p 134). A visit to the "Climate Change" page of Wikipedia provides evidence of the purposeful targeting of climate change science by these contrarian groups; Wikipedia is meant to be a collaborative online endeavour that can be edited and augmented by anyone with access to the site, yet the "Climate Change" page stated, at the time of writing, "This article is semiprotected indefinitely in response to an ongoing high risk of vandalism." For a member of the public seeking to become informed about the science and issue of climate change, the Internet is a daunting, unreliable and likely confusing medium of information.

Mass Media

The general public does not typically read scientific publications on climate change or engage directly with climate change scientists, and the Internet is only a venue that provides climate change information, or misinformation, for those who seek it out. Of the four ways that the public can obtain scientific information, mass media (both print and electronic) with its daily serving of news stories, is by far the public's primary source for climate change information. Vasile (2010) defines mass media as the "dissemination of information, ideas and entertainment by the use of technological media such as radio and television, film, the press, the publications and advertising" (p 26). Unfortunately, mass media is a major hurdle to an improved public understanding of the issue of climate change because the media reports on science issues infrequently, and when it does, its stories are often inaccurate and filled with exaggerated controversy (Moser and Dilling 2004, p 36).

The mass media's current attention to science is disproportionate to the importance and societal implications of scientific discoveries to the public. Science reporting has continually declined from its height during the Second World War, when there was heightened public interest in space travel, to its current role as a niche subject area in mass media (Weigold 2001, 166). This disconnect between the importance of science to the public and the reporting of science to the public is a key barrier to the contemporary understanding of science issues by the public. Compounding the issue that less space and time is being given to science reporting is the fact that most journalists who report on science lack a background in science (McBean and Hengeveld 2000, 18). This means that many science reporters, without the necessary background in science, struggle to understand the scientific stories they are reporting. Weigold (2001) reveals that although most journalists have a college degree (84 per cent of newspaper journalists and 95 per cent of newsmagazine journalists), less than 3 per cent of these degrees include a major in a science-related field (p 169). Even if a mass media outlet has a knowledgeable and specialized science journalist, he or she may lack the status within that mass media organization for the stories that the journalist sees as important to be given priority. It is no surprise that media reports on science issues often contain incorrect or outdated scientific information. Compared with other types of general news reporting, climate change reporting has more "scientific or technical inaccuracies, misquotations, significant omissions, exaggerations, and distortions of emphasis" (Weigold 2001, 132). Many mass media outlets also share their news stories with each other; this cost-saving practice results in fewer viewpoints and fewer people deciding what is newsworthy.

The primary goal of mass media outlets is to attract readers and sell their products, which means that the desire to entertain often trumps the desire to inform. In order to make journalistic pieces more entertaining, mass media often exaggerates the debate among scientists on climate change and de-emphasizes the consensus among these scientists (Moser and Dilling

2004, 36). With climate change's complexity, far-reaching environmental consequences and public policy ramifications, mass media journalists have little difficulty crafting stories on climate change that include drama and controversy. In order to create this entertaining controversy, a journalist may contrast the views of climate change scientists with climate change skeptics, doomsayers and other types of contrarians. Gelbspan (2010) provides an example of this on his website, *The Heat Is Online*:

> The [*New York*]*Times* quotes, among others, an obscure skeptic named Christopher Monckton whose website claims he has proved climate change does not exist – and that solar and wind energy create as much warming as burning coal and oil. To people in the climate community, Monckton has long been regarded as a clown – a grade C skeptic. But, for some reason, the [*New York*] *Times* saw fit to quite [sic] him as an authority. (Italics added; para 51)

This journalistic practice creates public uncertainty and confusion because it gives the views of nonexperts attention and credibility equal to that of climate change scientists.

Seeking out controversy and dissent is not limited to reporting of climate change science but extends to many areas of science reporting; Zehr (2000) describes how "on occasion, journalists may develop controversy where none previously existed, or sustain it by soliciting opposing arguments by expert scientists" (p 86). As well as creating drama, this practice of emphasizing polarized views is seen by journalists as a way to be objective and balanced in their reporting. However, it is irresponsible of mass media to give equal weight to conflicting viewpoints when the evidence so clearly supports one viewpoint, and the result of this practice is a confused public. Moser and Dilling (2004) argue that the mass media's perpetuation of a polarized climate change debate not only confuses the public, but it also turns the public off "not just from the debate but from the issue and urgency itself" (p 37).

Educators

Science educators are faced with the challenge of teaching students about climate change. As members of the public, both teachers and students are influenced by the controversial and confusing messages that the mass media produces about climate change. However, science educators have an opportunity and a responsibility to become more informed and certain about the science of climate change so that they can counteract the damaging influence of mass media and present their students with a more accurate idea of the issue. Climate change is one of the most important concepts that science educators teach, because there is no doubt that students will hear about this issue outside of the science classroom and that climate change will have an effect on their future lives.

In addition to the communication challenges presented by scientists, the Internet, and mass media, teachers also face additional challenges in the public's perception of climate change. Hulme (2010) describes how climate change is an example of "postnormal" science, where the cost of mistaken decisions can be enormous, but the information needed to make these decisions is lacking. The complex and postnormal nature of the climate change issue often leaves students and other members of the public feeling daunted by the depth of the issue or unqualified to enter the debate. In other words, people may feel that they don't understand the climate change issue or that it is too big for them to solve, so they don't care. Moser and Dilling (2004) identify another public perception hurdle when they describe climate change as a "creeping" problem (p 34). Because the effects of climate change are less immediate and instead slowly accumulate over time, there is less urgency to address the problem. Ungar (2000) argues that scientific claims must compete in an attention economy and those with day-to-day relevancy have greater currency. In other words, people may believe that climate change is far off in the future and they have more urgent things to think about, so they don't have time to care. Some scientists and mass media appeal to fear and guilt in an attempt to motivate the public to increase their sense of urgency about the issue (Moser and Dilling 2004, 37). This strategy is not constructive and may have the opposite effect of disengaging the public. In other words, climate change means a potentially dark and catastrophic future, so they don't want to think about it.

For science educators to become more knowledgeable on the issue of climate change is no easy task. Educators have limited time or resources to engage with the primary literature in any area of science and have limited opportunities to engage with scientists first hand. Instead, they must rely on the Internet and mass media, in spite of the limitations of these media.

Although becoming more current and increasing knowledge is clearly beneficial to both educators and their students, educators need not devote all of their time to climate change research in order to reduce public mistrust and misinterpretation of media reports on climate change. Indeed, doing so would create a teacher-to-student deficit model of one-to-many communication, which is already a criticism of and problem with the scientific community's communication efforts. Instead, educators can focus on teaching students critical thinking skills and media awareness in the context of climate change. Teaching students to look for bias and evaluate sources on the Internet or in mass media helps students distinguish what is credible and what is not. Focusing on these skills also encourages students who are science literate and media savvy in contexts beyond the climate change issue. Having students apply the climate change information they have learned in class to look critically at popular film, for example, is one way to promote critical thinking. For example, in my own classroom I have had my students analyze the inaccuracies in the 2004 Hollywood climate change disaster movie *The Day After Tomorrow*. Because this pseudoscience film contains so many inaccuracies, I found it to be an accessible medium for students to test and hone their critical thinking.

Science educators often teach science in a compartmentalized way, addressing each scientific topic as if it is separate and unrelated from other areas of science. This is evidenced in the way that teachers at the secondary level are trained to be biology, chemistry or physics teachers and that integrated science courses, such as Alberta's Science 10, Science 20 and Science 30 courses, are often taught as having four separate and isolated components. Chambers (2009) describes two reasons that educators have difficulty with the interdisciplinary nature of climate change education: "(1) secondary science teachers in Alberta are discipline specialists; and (2) high school classes are segregated into the distinct subject areas" (p 5). An environmental education issue such as climate change is not served well by the learning silos that this type of teacher training and structure create. Instead, science educators should work with and be supported by teacher education and curriculum developers, to show the interrelationships between different areas of science and the links among the issues.

Hulme (2010) argues that the postnormal nature of climate change requires an extended peer community to best address this complex issue; this means including more stakeholders in the debate over how to deal with climate change. Who the important stakeholders are in this issue is part of this discussion. Educators can make this aspect of climate change better understood and more meaningful by having students identify and role-play the various stakeholders in a teacher-mediated debate. This classroom strategy can help students appreciate the various perspectives in this complex issue. Science educators can also reach out to the scientific community and work to bring experts into the classroom—physically and/or virtually. Many research institutions and universities have outreach programs that facilitate video conferencing or classroom visits by scientists. This type of direct relationship is beneficial to educators, students and scientists alike.

The Center for Integrated Study of the Human Dimensions of Global Change website (http://hdgc.epp.cmu.edu/) contains a number of useful resources for educators, including a teachers' guide endorsed by the US National Science Teachers Association (NSTA). The teachers' guide includes lesson plans, a student-friendly list of the top 10 things you need to know about climate change, links to publications of primary literature and links to other reputable websites. A more action-focused resource for teachers is the short (70 pages) book *Stop Global Warming: The Solution is You*, by Laurie David. The book includes many personal strategies that teachers can share with their students for reducing climate change impact.

Conclusion

The public's trust of climate change science has been eroded through a lack of effective communication on the part of scientists, by the efforts of contrarians largely using an uncensored Internet to get their message out and by the exaggerated controversy in mass media messages. The urgency and importance of climate change has been diminished; Moser and Dilling (2004) argue that the solution to the climate change communication problem is to use highly credible and legitimate "trusted messengers" (p 41). They question whether scientists are suitable for this role, but do not provide a clear statement of who the trusted messengers should be. I would argue that science educators can and should work to become one of these trusted messengers of climate change information. By developing students' critical thinking skills, science educators can help create a future generation of people with re-established public trust and certainty in the scientific information about climate change.

Bibliography

Chambers, J M. 2009. "Teaching About Climate Change: Science Teachers' Experiences and Challenges." Oral paper presented at the International Science Education Conference, Singapore, November 25.

Corbett, J B, and J L Durfee. 2004. "Testing Public (Un)Certainty of Science: Media Representations of Global Warming." *Science Communication* 26, no 2: 129–51.

David, L. 2006. *Stop Global Warming: The Solution Is You*. Golden, Colo: Fulcrum.

Day After Tomorrow, The. 2004. Film. Dir R Emmerich. Los Angeles: 20th Century-Fox.

Elam, M. 2004. "Contemporary Science Communication as a World of Political Invention." *Science as Culture* 13, no 2: 229–58.

Gelbspan, R. 1998. *The Heat Is On: The Climate Crisis, The Coverup, The Prescription*. New York: Perseus Books.

———. 2010. "U.S. Press Coverage of the Climate Crisis: A Damning Betrayal of Public Trust." *Heat Is Online*. Available at http://tinyurl.com/3vhg3mx (accessed November 21, 2011).

Hulme, M. 2010. "Claiming and Adjudicating on Mt Kilimanjaro's Shrinking Glaciers: Guy Callendar, Al Gore and Extended Peer Communities." *Science as Culture* 19, no 3: 303–26.

Inconvenient Truth, An. Documentary film. Dir D Guggenheim. Hollywood, Calif: Paramount.

McBean, G A, and H G Hengeveld. 2000. "Communicating the Science of Climate Change: A Mutual Challenge for Scientists and Educators." *Canadian Journal of Environmental Education* 5, no 1: 9–23.

Moser, S C, and L Dilling. 2004. "Making Climate Hot." *Environment* 46, no 10: 32–46.

Ungar, S. 2000. "Knowledge, Ignorance and the Popular Culture: Climate Change Versus the Ozone Hole." *Public Understanding of Science* 9, no 3: 297–312.

Vasile, C. 2010. "From Mass Media and Education to Mass Media Education." *University of Ploieşti Bulletin Educational Sciences Series* 62, no 1A: 25–30.

Wikipedia. nd. "Climate Change." Available at http://en.wikipedia.org/wiki/Climate_change (accessed April 3, 2011).

Weigold, M. 2001. "Communicating Science: A Review of the Literature." *Science Communication* 23, no 2: 164–93.

Zehr, S C. 2000. "Public Representations of Scientific Uncertainty About Global Climate Change." *Public Understanding of Science* 9, no 2: 85–103.

Zivkovic, B. 2010. "Why Is 'Scientists Are Bad Communicators' Trope Wrong." *A Blog Around the Clock*. February 14. Available at http://scienceblogs.com/clock/2010/02/for_a_very_long_time.php (accessed November 21, 2011).

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Using Climate Change to Create Rich Contexts for Physics and Chemistry Education

Brian Martin and Peter Mahaffy

Abstract

Climate change education crosses many disciplinary boundaries, creating barriers for locating it within a specific disciplinary curriculum. We argue that students can acquire significant understandings of climate change if it is introduced as a rich context around which we can scaffold important concepts in physics and chemistry.

In an ideal world, curricula would be malleable and change quickly in response to important events relevant to the lives of students. Ours is not an ideal world, and the rate of curriculum change is glacial at best. As well, science curricula are dominated by disciplinary concerns. For these reasons climate change education is problematic in the classroom—it just doesn't seem to fit! We would like to suggest a pragmatic strategy to work within existing curricula and at the same time educate students about the underlying science of climate change. Our approach will be to give students an evidentially rooted understanding of some of the basic concepts of climate change and, at the same time, complete existing curricular goals. In this paper we will use the Alberta science curriculum as our model, but the argument could be easily extended to other national and international curricula.

Useful Student/Teacher Resources

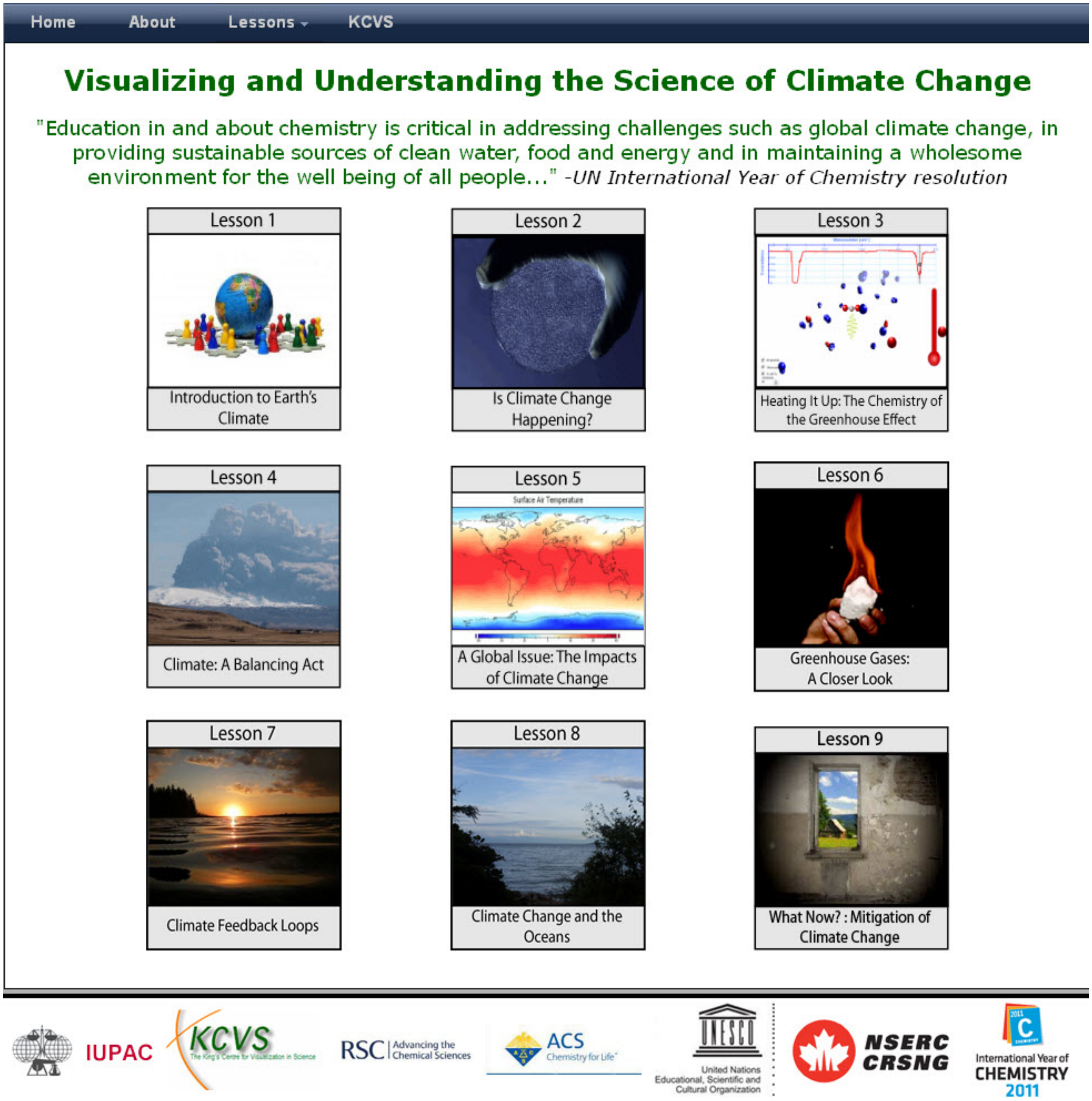
One of the known barriers to addressing climate change in the classroom is the lack of easily accessible and usable curricular materials. There is no shortage of wonderful visualizations and in-depth discussions of many diverse aspects of global climate change. Three examples are the NASA Earth Observatory (http://earthobservatory.nasa.gov), the National Oceans and Atmospheric Administration Climate Service (www.climate.gov/#climateWatch) and Real Climate (http://www.realclimate.org). These are rich resources but, by virtue of their magnitude, can also be overwhelming. To help make the complex science of climate change more tractable in the classroom, the King's Centre for Visualization in Science (KCVS), the Royal Society of Chemistry, the American Chemical Society and UNESCO have developed an interactive online resource—Visualizing and Understanding the Science of Climate Change (www.explainingclimatechange.ca) under the umbrella of an International Union of Pure and Applied Chemistry International Year of Chemistry 2011 project. This is a teacher- and student-friendly resource intended for students between the ages of 16 and 19 years and comprises nine lessons. Figure 1 is a splash screen from this resource. Each lesson contains interactive simulations, video and assessment items. These could be used as either stand-alone teaching packages or resources for adaptation to the classroom. Each lesson includes identification of key concepts as well as test-your-knowledge items. An extensive online glossary also helps students and teachers navigate the at times jargon-laden world of climate change. All of the lessons operate within a custom-made content delivery system.

In what follows we will show how resources from Visualizing and Understanding the Science of Climate Change can help develop the rich context that illustrates how climate change topics can be introduced into traditional physics and chemistry lessons.

Understanding Climate Change Through Rich Contexts

The Alberta science curriculum rests on four foundational pillars: attitudes, knowledge, STS (science, technology and society) and skills. The following exemplars include a correlation to illustrate how a specific curricular aim is met through a climate change topic. We also correlate this with the Visualizing and Understanding the Science of Climate Change resource. A detailed correlation is provided in Table 1.

Figure 1: Splash screen from the Visualizing and Understanding the Science of Climate Change site, which is freely available to all teachers at www.explainingclimatechange.ca



Visualizing and Understanding the Science of Climate Change

"Education in and about chemistry is critical in addressing challenges such as global climate change, in providing sustainable sources of clean water, food and energy and in maintaining a wholesome environment for the well being of all people..." *-UN International Year of Chemistry resolution*

Lesson 1: Introduction to Earth's Climate
Lesson 2: Is Climate Change Happening?
Lesson 3: Heating It Up: The Chemistry of the Greenhouse Effect
Lesson 4: Climate: A Balancing Act
Lesson 5: A Global Issue: The Impacts of Climate Change
Lesson 6: Greenhouse Gases: A Closer Look
Lesson 7: Climate Feedback Loops
Lesson 8: Climate Change and the Oceans
Lesson 9: What Now? : Mitigation of Climate Change

Table 1: Correlation between climate topics, Alberta science curriculum and Visualizing and Understanding the Science of Climate Change

Climate Topic	Physics/Chemistry Topic(s)	Alberta Science Curriculum Linkage	Visualizing and Understanding the Science of Climate Change
Mass and molar mass of the atmosphere	Newton's 2nd Law—force, mass, acceleration, pressure, mole	Physics: 20-B1.3k,20-B2.6k, 20-B2.3s	Lesson 1, Topic 3
CO_2 concentration in the atmosphere	Stoichiometry, mole	Chemistry: 20-D1.1-5k, 20-D1.1sts, 20-D2.2sts,30–C2.3sts	Lesson 6, Topic 2
Greenhouse gas heating in atmosphere	KMT, thermal energy, absorption of electromagnetic energy by gases	Chemistry: 20-B1.2k, 30-A2.2k, 30–C2.3sts Physics:30-C1.2k, 30-C2.2k, 30-D2.2k	Lesson 3, Topics 1–5 Lesson 6, Topics 1–5
Spectral windows	Electromagnetic spectrum	Physics:30-C1.2k, 30-C2.2k, 30-D2.2k	Lesson3, Topic 3 Lesson 6, Topics 1–5
Isotopic proxy measurement of temperature	Stable nuclear isotopes	Physics: 30-D3.2k, 30-D3.2sts	Lesson 2, Topic 1
Ocean pH	Acid-base chemistry, logarithmic functions	Chemistry: 20-C2.2,-5k,20_c2.2sts 30-D1.1-8k, 30-D1.sts, 30-D2.1k, 30-D2.1sts, 30-D2.2s	Lesson 8, Topics 3–5

Calculating the Mass of the Atmosphere

Physics and chemistry are at their best when, with simple tools and very basic information, a student can discover something remarkable. One of the most basic ideas in understanding climatic changes in atmospheric temperature requires that we know the mass of the atmosphere. While this may seem to be a complex task, it is, in fact, accessible to students at a Grade 11 level. Start with a very basic piece of knowledge—atmospheric pressure. Many students will already know that the atmospheric pressure, at sea level, is roughly 100 kPa. Since 1 Pa is $1N/m^2$, we know that each square metre of Earth supports a column of air weighing 100 kN. Applying Newton's second law leads to the result that each square metre supports 10^4 kg of air. The rest is simple geometry! The surface area of a sphere is given by $SA = 4\pi R^2$. With $R = 6.4 \times 10^6$m, this leads to a mass of $M = (10^4 kg / m^2)4\pi(6.4 \times 10^6 m)^2 = 5.1 \times 10^{18} kg$.

If students haven't already challenged you on this you may want to ask them what assumptions have been made in this calculation. The most obvious is the assumed constancy of *g*, the local acceleration of gravity. Since roughly 98 per cent of Earth's atmosphere is contained in the bottom 30 km, you could ask students to estimate how big an error you are making by using this assumption.

Knowing the mass of the atmosphere, it is relatively easy to find the number of moles in the atmosphere. Since air is approximately 79 per cent N_2 and 21 per cent O_2, the weighted average atomic weight of air is 28.8 g/mol. The number of moles in the atmosphere is then $molar\ mass = \frac{5.1 \times 10^{21} g}{28.8\ g/mol} = 1.8 \times 10^{20} mol$.

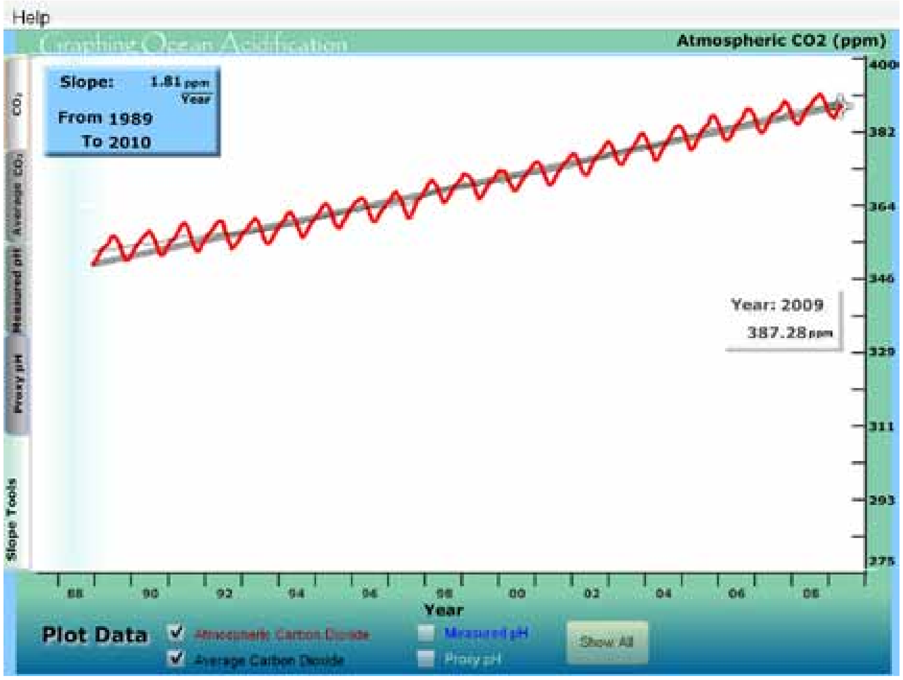
Armed with this, a student can now begin to understand how to calculate the change in concentration of atmospheric CO_2 through the burning of fossil fuels.

Calculating Atmospheric CO_2 Concentrations

Most hydrocarbon-based fuels used today can be approximated to range in chemical composition from octane (C_8H_{18}) to diesel ($C_{12}H_{26}-C_{16}H_{34}$). Let's assign a typical chemical formula of $C_{12}H_{26}$ to represent a burning fossil fuel. By balancing the chemical reaction equation we can determine the amount of CO_2 produced in a combustion reaction for a particular amount of hydrocarbon: $2\,C_{12}H_{26} + 37\,O_2 \rightarrow 24\,CO_2 + 26\,H_2O$.

By comparing the molar masses of $C_{12}H_{26}$ and CO_2, students can readily understand the leveraging effect of fossil fuel combustion. Roughly 3.2 times as much CO_2 (by mass) is released when a certain amount of fossil fuel is burned. This can quickly lead to some revealing calculations. A typical barrel of oil has a mass of 135 kg and, when burned, releases 425 kg of CO_2. Another way to state this is that for every barrel of oil burned, $\frac{425\ kg}{0.044\ kg/mol} = 9.7 \times 10^3 mol$, 9.7×10^3 mol of CO_2 are released. Since there are 1.8×10^{20} mol in the atmosphere, each barrel of oil, when burned, changes the atmospheric concentration of CO_2 by $\frac{9700\ mol}{1.8 \times 10^{20} mol} = 5.4 \times 10^{-17}$, which is equivalent to 5.4×10^{-11} parts per million (ppm).

Figure 2: Growth of CO_2 in Earth's atmosphere between 1988 and 2009, showing an average increase of 1.83 ppm/a



Since 30 billion barrels of oil are burned annually, the expected increase in atmospheric CO_2 from oil burning should be on the order of 1.6 ppm. In reality only about 37 per cent of the CO_2 produced comes from oil (40 per cent comes from coal combustion and the rest comes from natural gas and the curing of concrete). The expected annual change in CO_2 concentration is therefore about 4.8 ppm.

How does this number relate to what we know about CO_2 concentration in Earth's atmosphere? Figure 2 shows the data for atmospheric concentration of CO_2 as measured from the Mauna Loa observing station between 1988 and 2009, plotted with an interactive tool created for the Visualizing and Understanding the Science of Climate Change site. The average rate of increase of CO_2 concentration over the past 20 years is 1.8 ppm a^{-1}. This is the correct ball-park figure according to our calculations and also raises the question: If we calculated an increase of 4.8 ppm but see an increase of only 1.8 ppm· a^{-1}, where is the rest of the CO_2 going?

Ocean Acidification

One of the most disturbing discoveries in climate science of the past 20 years is the effect that increased absorption of human-generated CO_2 is having on the subtle chemistry of Earth's ocean. Our previous calculations hinted that most of the CO_2 introduced into our atmosphere by fossil fuel burning was ending up elsewhere. Much of this "missing" CO_2 is being absorbed into the ocean. This is an excellent application of acid-base chemistry and can be characterized through the following reactions:

$$CO_2(g) + H_2O \Leftrightarrow H_2CO_3(aq)$$

$$H_2CO_3(aq) \Leftrightarrow H^+ + HCO_3^-(aq)$$

$$HCO_3^-(aq) \Leftrightarrow H^+ + CO_3^{-2}(aq)$$

The ocean buffers atmospheric CO_2 through the nimble dance between concentrations of carbonic acid (H_2CO_3) and the bicarbonate and carbonate ions (HCO_3^-, CO_3^{-2}). As CO_2 is absorbed into the ocean, the buffering action of the ocean does some subtle things. Increased production of carbonic acid is accompanied by an increase in acidity (the number of hydronium ions [H^+]) and decrease in pH of the oceans. This in turn causes a shift between the equilibrium of bicarbonate and carbonate ion concentration. Why does this matter? Marine organisms such as corals and mollusks secrete $CaCO_3$ in several different forms, and much of the base of the aquatic food chain is critically dependent on carbonate ion concentration. As the pH of the ocean drops, so too does the carbonate ion concentration, and the solid shells of certain marine organisms become soluble in water. Figure 3 shows an ocean acidification digital learning object from Visualizing and Understanding the Science of Climate Change that enables students and teachers to explore how the changing ocean pH can be related to carbon usage as expressed in atmospheric CO_2 concentration.

To quantify this, consider the change in ocean pH since the Industrial Revolution. The pre-Industrial Revolution pH was 8.2, while today the ocean pH is 8.1. That doesn't sound like much of a change, but let's calculate how much the actual hydronium ion content (ie, acidity) of the ocean has changed.

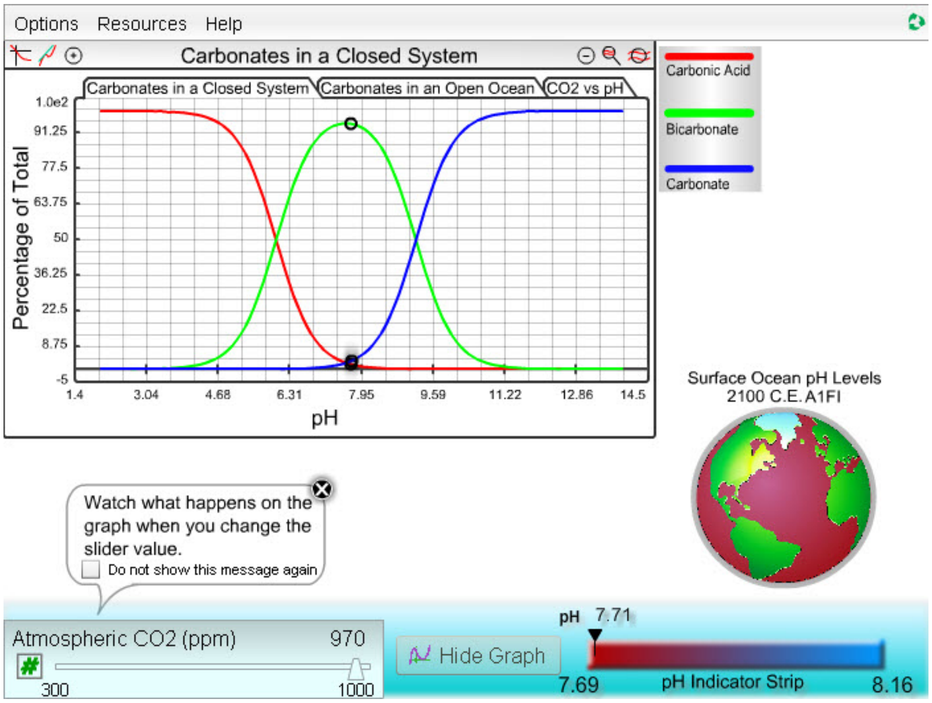
By definition a pH of 8.2 is given by $pH = -\log_{10}[H^+]$. So the hydronium ion concentration (pre-Industrial Revolution) was $10^{-8.2} = 6.31 \times 10^{-9}\ mol\ L^{-1}$.

A pH of 8.1 corresponds to an H^+ concentration of 7.94×10^{-9} mol L^{-1}. This represents an increase of 25 per cent in the acidity of the ocean. This is already (along with temperature effects) wreaking havoc on a wide variety of marine organisms, including plankton and those found in coral reefs. Currently Earth's ocean is more acidic than at any time in the past 20 million years (Weston 2000; Archer 2007; Interacademy Panel on Global Issues [IAP] 2009)! This will only worsen over the next century, and the results could be catastrophic unless the situation is addressed now.

Using Isotopic Ratios to Measure Temperature

Isotopes and isotopic ratios provide remarkable insights into Earth's climate and enable us to determine such things as the extent of ice sheets and air temperature in paleoclimate history. The isotopic ratio of oxygen is one of the most useful proxies for determining temperatures of the distant past. Since ^{18}O is slightly heavier than ^{16}O, water that contains ^{18}O will have slightly different physical properties than water containing light oxygen (ie, ^{16}O). Water containing light oxygen evaporates more readily than water containing heavy oxygen; conversely, water containing heavy oxygen condenses more readily. This means that as temperatures drop, so too does the atmospheric concentration of water containing heavy oxygen. Polar ice cores (from either Greenland or Antarctica) provide us with what can be called temperature museums. When the ice from a particular depth in an ice core is analyzed, a lower concentration of ^{18}O tells us that the ice was formed when temperatures were lower. By correlating ice core depth with time and ^{18}O concentration with temperature, climatologists are able to reconstruct Earth's climate history nearly 1 million years into

Figure 3: An applet that enables students to explore the relationship between atmospheric CO2 concentration and ocean chemistry



Watch what happens on the graph when you change the slider value.

☐ Do not show this message again

Atmospheric CO2 (ppm) 970

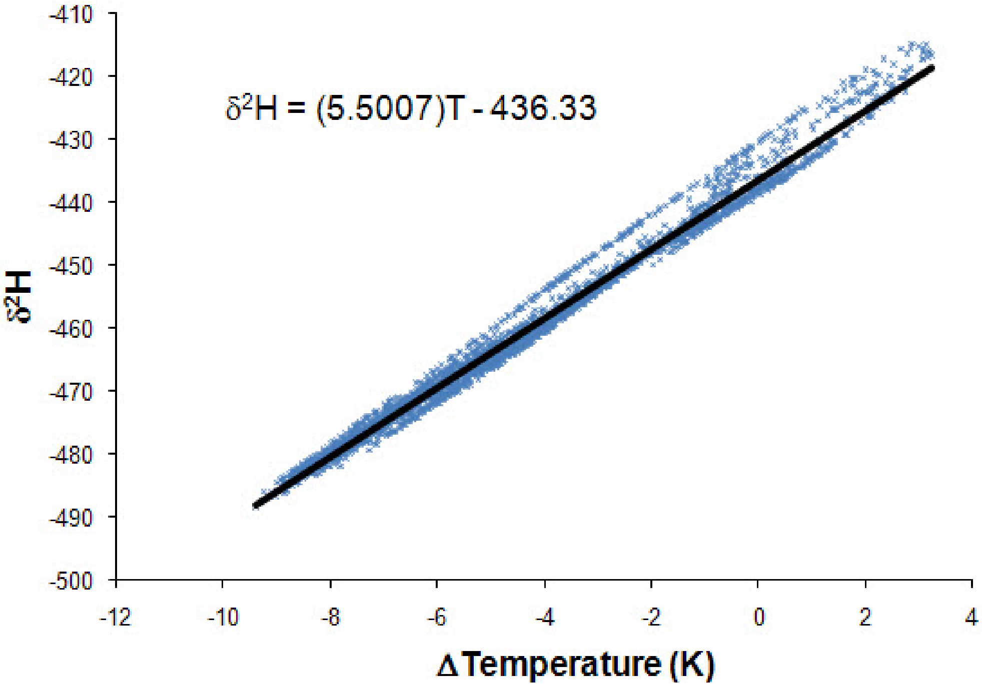
pH 7.71

the past. Deuterium isotope ratios are also commonly used to provide temperature proxies, and Figure 4 illustrates the correlation between the change in deuterium (relative to a fixed standard) and temperature for an ice sample taken from the Vostok ice core, in Antarctica. The data spans 420 ka and shows a strong linear relation between change in isotope concentration and change in deuterium. The Visualizing and Understanding the Science of Climate Change digital learning objects also include a very useful applet that allows students to investigate the Vostok and Dome C Antarctic data sets, which show temperature, CO_2, N_2O and CH_4 ice-core data spanning nearly 1 million years of climate history.

How Greenhouse Gases Heat the Atmosphere

One of the first suggestions that gases in Earth's atmosphere may contribute to warming the planet came from Fourier in the 1820s. In 1896, Svante Arrhenius (Arrhenius 1896) published the first paper actually identifying CO_2 as a greenhouse gas and calculated the heating effect of CO_2 on the planet. So how does a gas such as CO_2 contribute to atmospheric warming? The answer has to do with both the quantum nature of molecular absorption of electromagnetic radiation and the collisions that occur between molecules. A CO_2 molecule is able to absorb infrared radiation in selective wavelength bands. The molecule is able to undergo both stretching and bending mode vibrations when it absorbs infrared radiation that Earth radiates back into space. Most of this absorption occurs in the troposphere, where the rate of molecular collisions is also very high. The mean time between collisions of an excited CO_2 molecule and N_2 and O_2 gas molecules is very short, and a significant number of excited CO_2 molecules will lose their vibrational energy in an energy exchange process called *collisional de-excitation*. This effectively transforms infrared radiation into translation energy of the gas in the atmosphere, hence heating the atmosphere. An interactive digital learning object available on the Visualizing and Understanding the Science of Climate Change website allows students to see how molecular vibration is wavelength dependent and to see how collisional de-excitation is able to transform infrared radiant energy into thermal energy.

Figure 4: Linear relationship between change in deuterium abundance and change in temperature (data from NOAA Paleoclimatology Ice Core Gateway)



Spectral Windows and Greenhouse Gases

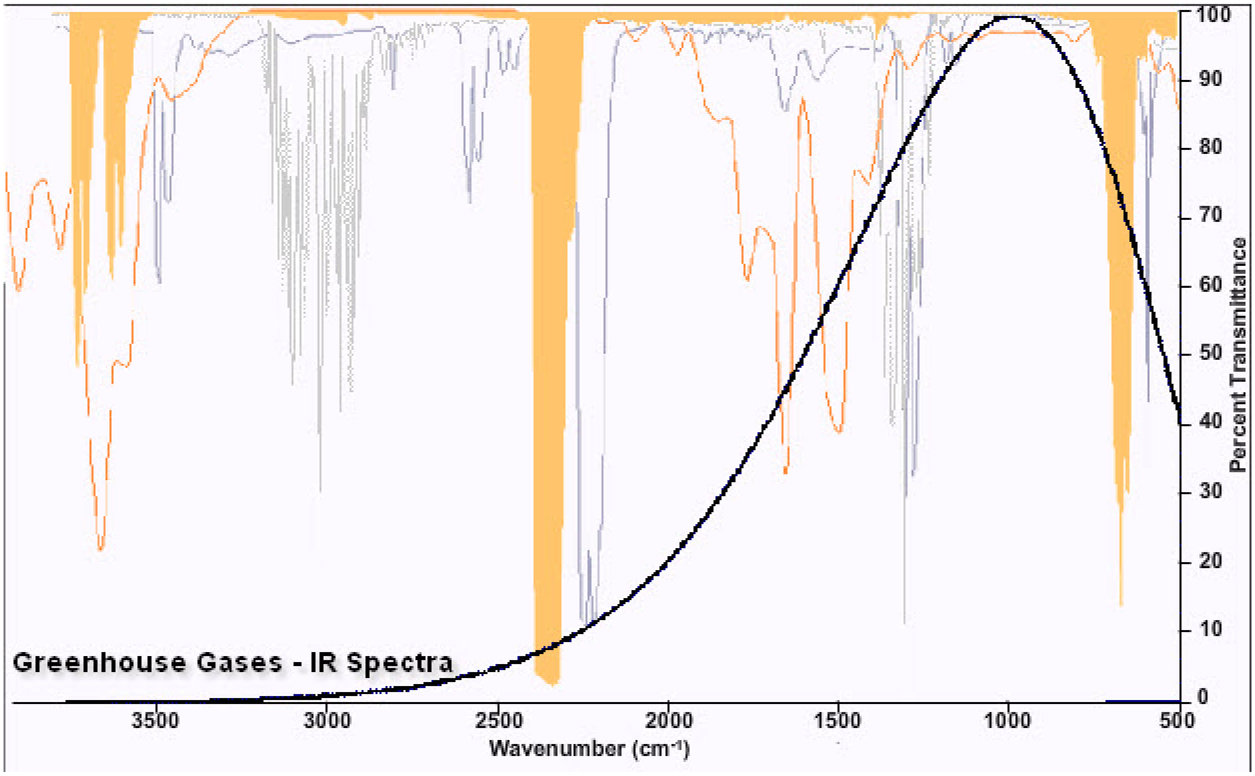
Earth receives energy from the sun in the spectral range that peaks around 550 nm (with the Sun radiating at 5,800K) and emits back into space in the far infrared, peaking at about 10,000 nm. Without the benefit of greenhouse gases this would create a radiative equilibrium and establish a temperature at Earth's surface roughly 30 degrees cooler than it currently is. Greenhouse gases are vital to the life of Earth. Figure 5a shows a blackbody curve consistent with a mean global surface temperature of 15 C. Superimposed on this are absorption profiles for four prominent greenhouse gases: water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Between the absorption lines are regions (or windows) through which infrared radiation can still pass and provide cooling to the planet. Figure 5b shows the same profiles, but this time with a number of additional greenhouse gases (with large contributions from human activity) present. Note that these gases will absorb near the peak of Earth's blackbody emission and have the potential to cause significant warming even in low concentrations.

These profiles have been scaled to fit the blackbody curve and illustrate their relative importance in blocking infrared radiation in the atmosphere. The net effect is to close the spectral windows, which will shift the radiative equilibrium of the planet to create a warmer atmosphere—ie, global warming. Figures 5a and 5b were produced using a digital learning object available on the Visualizing and Understanding the Science of Climate Change website.

Conclusions

One idea capturing global attention in the past two years is that science has an important role to play in helping to understand and address our planetary boundaries, within which humanity can operate safely (Rockström et al 2009). Rockström and his coauthors suggest that human activity to change earth's climate is one of three areas where we have already

Figure 5a: Absorption spectra of four prominent greenhouse gases shown in relation to the blackbody spectrum emitted by Earth's surface



overstepped the planetary boundary of a safe space for human development. Given this, it is especially urgent that we address climate change in our science curricula. We have argued that despite the apparent lack of space for climate change education within current science curricula, there are strategies that can be adopted to ameliorate this omission.

We have presented six exemplars of topics that are both included in the Alberta science program of studies and important for students to develop an evidence-driven understanding of global climate change, one of our important planetary boundaries. All of these (and many more) are supported by well-developed resources available at the Visualizing and Understanding the Science of Climate Change website. Teachers are encouraged to consider using the rich context of climate change education as a strategy to motivate learning in the existing science curriculum and equip students to make sense of concepts that they need in order to function as informed citizens. Ideally, teachers could work collaboratively and across disciplinary boundaries to coordinate how these concepts can be presented in biology, chemistry, physics and math courses and to make connections to political and economic concepts introduced in social studies courses. Climate change science will continue to provide us all with relevant and conceptually robust topics to address within science teaching at all levels.

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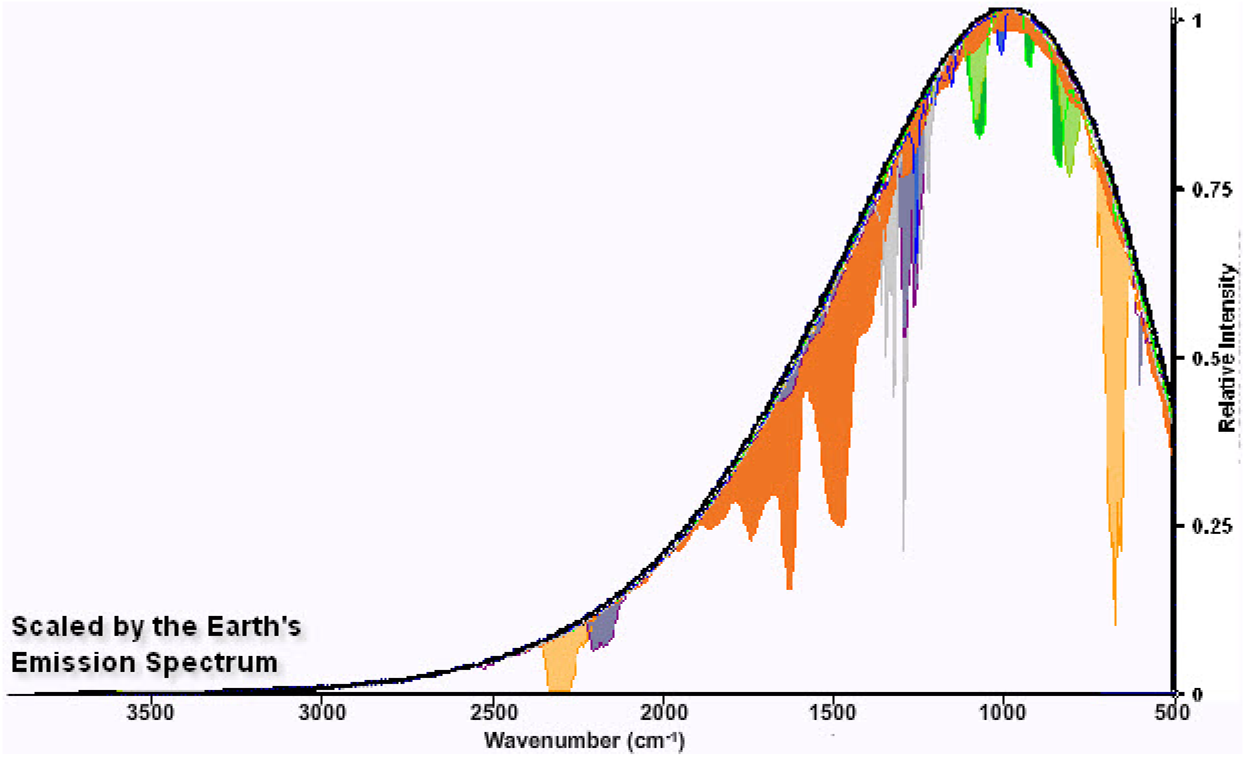
Figure 5b: The blackbody spectrum of Earth and the effectively closing spectral window caused by greenhouse gases in the atmosphere. Some of the gases most effective at absorbing in the peak spectral region, such as fluorinated gases like CFCs, are anthropogenic.



science, biology and environmental studies, worked on the development of digital learning objects. In 2010/11, the climate change science team included Denyse Dawe, Anna Schwalfenberg, Matthew Price, Amanda Vanderhoek, Darren Eymundson, Kristen Tjostheim and David Dykstra. The Royal Society of Chemistry (UK) provided staff members and teachers to review the interactive materials, and UNESCO, ACS, IUPAC, RSC and the Federation of African Societies of Chemistry are facilitating their global dissemination.

Note

[1] National Oceanic and Atmospheric Administration (NOAA) Ice Core Gateway. www.ncdc.noaa.gov/paleo/icecore/antarctica/vostok/vostok_data.html (accessed November 22, 2011).

References

Archer, D. 2007. *Global Warming: Understanding the Forecast*. Oxford, UK: Blackwell.

Arrhenius, S. 1896. "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground." *Philosophical Magazine and Journal of Science* Series 5, vol 41, no 251: 237–76.

Interacademy Panel on International Issues (IAP). 2009. Statement on Ocean Acidification. C Zhu and H Alper, chairs. Trieste, Italy: Academy of Sciences for the Developing World.

Martin, B, and P Mahaffy. 2010. "Our Climate, Our Change–Using Digital Learning Objects to Present the Complex Science of Global Climate Change." Proceedings of the 9th International Conference on Computer Based Learning in Science, Warsaw, Poland, July 4–7.

Rockström, J, W Steffen, K Noone, Å Persson, F S Chapin III, E F Lambin, T M Lenton et al. 2009. "A Safe Operating Space for Humanity." *Nature* 461: 472–75.

Weston, Ralph E. 2000. "Climate Change and Its Effect on Coral Reefs." *Journal of Chemical Education* 77, no 12: 1574.

Why Scientific Literacy Must Be a Focus of Science Education: An Argument for the Literate Citizen

Leslie D Heinsen

Today's citizens are constantly bombarded with scientific information, some rooted in fact and some in fiction. Therefore, it is imperative that all citizens, through their science education, be given the tools to evaluate scientific information and assess its value. The ability to use this evaluation process is, in part, what it means to be scientifically literate. At a time when the vast majority of the public is considered scientifically illiterate, but should be engaged in public discussion of science issues, education should do its part to ensure a literate populace. The purpose of this paper is to define scientific literacy, argue why scientific literacy must be a part of science education and suggest some possible avenues that can be followed to achieve literacy goals.

What Is Scientific Literacy?

An examination of the literature produces many definitions of scientific literacy. Laugksch (2000) describes scientific literacy as the science the public ought to know. Scientific literacy has been described as the science necessary for citizenship by Kolstø (2001), and Brossard and Shanahan (2006) suggest that it is what a population needs for a public understanding of science. Fensham and Harlen (1999) place scientific literacy along a continuum with lack of scientific understanding at one end of the continuum and the understanding possessed by scientists at the other end. Others have broken down the term into separate subcategories. Laugksch (2000) gives a lengthy historical account of scientific literacy and cites Shen's 1975 divisions of scientific literacy. This subdivision includes the term "civic scientific literacy" (Laugksch 2000, 77), a term that encompasses an average citizen's understanding of science that is sufficient to allow him or her to be involved in societal decision making. This definition is most appropriate for a school setting, given that the majority of students will not pursue further scientific studies or become directly involved in science as a profession. For the purpose of this discussion, the focus will be on the broad definition of scientific literacy that allows a person to function in daily life and contribute to societal decision making.

Civic Scientific Literacy

According to Miller (1998), civic scientific literacy is the level of scientific understanding required to read the newspaper. This definition includes understanding vocabulary and basic scientific principles, understanding scientific processes and appreciating how science affects the individual and society. Miller amended his definition somewhat in 2006, describing civic scientific understanding as the absolute minimum standard of scientific understanding, comparing it to functional literacy, which allows an individual to write his or her name and accomplish basic reading. Civic scientific literacy is the minimum standard of literacy I feel citizens must possess in order to function in society. For the remainder of this paper, when I use the term *scientific literacy* I will assume civic scientific literacy.

How Is Scientific Literacy Assessed?

Historically, scientific literacy has been measured using pencil-and-paper tests using issues that are the "intellectual foundation for reading and understanding contemporary issues" (Miller 1998, 206). Miller (2006) describes his 1988 assessment collaboration with Thomas and Durant, which included both closed- and open-ended responses, and thus attempted to address issues beyond the scientific facts typical of scientific literacy measures. Limitations of these tests have included the difficulty in assessing broad scientific coverage in telephone interviews and expanding questioning beyond true/false questioning. These tests have been administered to adults throughout the world. The outcomes of these tests indicate weak adult literacy and have made scientific literacy a focus of school education (Bauer, Allum and Miller 2007). Students' scientific literacy has also been assessed through a variety of measures, most notably the PISA (Program for International Student Assessment) exam. The goals of this test, and others like it, are to address the outcomes of school science and examine how school education has prepared students to be active citizens (Fensham and Harlan 1999). While the tests assess scientific content knowledge, I question the degree to which they address the real-life applications of scientific literacy. Other measures have been used globally to test adult and student literacy, but they test similar concepts and have produced similar results.

How Can We Develop Scientific Literacy?

Developing scientific literacy skills in the science classroom is no easy task. Scientific literacy is built through interactions with others, though meaningful interaction can be difficult in the classroom (Roth and Désautels 2004). Science classes assume that what is learned in class is applicable to real-life situations (Roth and Désautels 2004), but students typically have difficulty linking classroom learning to real life (Fensham and Harlan 1999). In Alberta, the minimum requirement for a high school graduate is two classes of science. I question whether this is enough science to render the students scientifically literate adults. When I compare the curriculum of a Science 14/24 class to the types of test questions used in assessing scientific literacy (see Miller 2006), I suspect that these courses are not enough. Interestingly, the course designed to make connections between science and society is for weaker students, while the content-focused courses are for stronger students (Roth and Désautels 2004).

Fensham (2002) identifies a lack of consensus among academics, science educators and teachers regarding what should be taught to address literacy concerns. Often the debate over curriculum boils down to content knowledge versus how to use the knowledge. According to Fensham, academics and many teachers wish to see increases in the content covered in class, focusing on biology, physics, chemistry and earth sciences, while science educators (not specifically teachers) want the curriculum less content dense and process driven. Kolstø (2001) points out that many science topics are too broad in their coverage and lack relevance to the students; both are issues that may impede the development of scientific literacy. *Relevance* is a term that appears frequently in the science literacy literature.

How literacy is achieved when there are so many conflicting viewpoints in education presents a challenge. Hobson (2001) provides some interesting suggestions to make science socially relevant and enhance literacy skills. Hobson suggests that teachers need to develop students' critical thinking skills, make science accessible and interactive, and focus on big ideas, essentially involving the students in their own education. Kolstø (2001) also advocates the development of *critical eye* when examining scientific evidence. The development of critical thinking skills, in my experience, requires more than content knowledge and the development of investigative skills. Hobson (2001) also feels that teachers need to focus on current science, make learning social by engaging the students in dialogue with their peers, address socioscientific issues in class and address the pseudoscience that mires scientific literacy. By addressing issues such as these, students are challenged to examine current events and evaluate them critically. Kolstø (2001) supports using socioscientific issues to build scientific literacy but acknowledges a number of challenges when taking this approach. Because socioscientific issues often represent very current scientific ideas, or what Kolstø calls "frontier science" (2001, 294), there is often a lack of consensus in the scientific community early in the development of these ideas. I would suggest that lack of agreement in the early days of the climate change dialogue, or at least the perceived lack of agreement, still hampers consensus in public discussion of the matter. This lack of agreement among scientists makes it difficult for students to trust the scientists and develop their own consensus on these issues.

Lee and Roth (2003) present some interesting perspectives on science education and the concept of scientific literacy. They suggest that current science education focuses on conforming to educational standards and adhering to the little-scientist model of education. This approach, they argue, does not address the social and political aspects of science. They emphasize the importance of making science socially relevant to students' lives. I believe that what they are advocating, in part, is an interdisciplinary approach to teaching, and I interpret this to mean that the time for teaching a particular subject in isolation is coming to an end. Kolstø (2001) hints at this cross-disciplinary approach regarding decision making, stating that science is a small part of a larger public decision-making process. This type of approach is more representative of the kind of evaluation that citizens engage in when they participate in public discussion of scientific issues.

Roth (2002) has suggested in earlier research that the entire educational system needs to be restructured, moving away from a traditional, hierarchical model, with the teacher disseminating knowledge to the students, toward a model that has students becoming active citizens who are actively involved in knowledge acquisition. This approach allows students to engage in authentic activities in the community and to guide the goals of their investigations. The specific example Roth described was an investigation into environmental concerns regarding the water supply of a local community. Students were involved in several aspects of the investigation, including water testing, communicating results with members of the community and working alongside other interested citizens.

Within my own teaching context, students are involved in a unique, student-led environmental initiative. This class, which will be offered for credit in the future, has students choose environmental topics and investigate them in a variety of ways chosen by the students themselves. My current students have been involved in placing solar panels on the roof of the school and will be studying real-time energy production. The students have also been active in their interaction with the public, including discussions with environmental experts, presenting their work to audiences at postsecondary institutions and involving their peers and teachers at the school level. Interactions such as these often extend beyond the student to other citizens as well (Roth 2002). This type of class is building the skills necessary for the students to become active, literate citizens.

These types of approaches build literacy by highlighting various perspectives surrounding an issue and also increase student participation because students are permitted a certain level of autonomy in their investigations. I believe this approach would also address current trends in differentiated instruction and modified assessment strategies. Alternatively, simulations are often used in science class to address current issues, in place of active investigation, but simulations are not authentic and fail to lead to the transfer of skills expected by educators (Roth 2002).

As the number of public policy issues continues to increase, the level of public engagement will also increase (Miller 1998). Collins and Evans (2002) have addressed the concept of nonexperts involved in dialogue with experts in the field and describe the level of understanding required to interact with these experts. Roth and Désautels (2004) explain that science has become open to discussion and address the limitations of expert knowledge and the value of nonexpert knowledge. While nonexpert knowledge can come in the form of anecdotal evidence and may easily be dismissed, citizens who are scientifically literate can evaluate this knowledge to promote their own points of view (Kolstø 2001), and experts can use it to guide their research and complement their opinion (Moore and Stilgoe 2009). Citizens must be scientifically literate if these public discussions are to continue.

Why Is Scientific Literacy Important?

Mass media is often the source of scientific information in both its portrayal of scientists and communication of scientific information (Brossard and Shanahan 2006). A quick scan of the local newspaper in mid-April 2011 revealed several topics of scientific interest: mapping the brain, the nuclear crisis in Japan and atherosclerosis in Egyptian mummies. While these articles were written with the average citizen in mind, their content requires a higher level of sophistication to address the content. For an individual, reciting correct bits of scientific trivia is not the same as understanding the science involved (Fenshem and Harlan 1999). Furthermore, to critically look at the information requires special skills. Without a strong foundation in school science, citizens cannot build the skills necessary to evaluate this kind of information. Miller (1998) notes that public awareness of scientific issues has increased significantly, making public understanding necessary. For Miller, the issues that require civic scientific literacy include not only interpreting news media, but also reading and interpreting labels on our food, fixing vehicles, addressing health and medical issues, and evaluating biotechnology—or any number of other science-related issues that affect our daily life.

Testing in European Union and United States reveals that less than 30 per cent of those tested were scientifically literate, and two-thirds of the highest-ranking individuals could not understand stem cells, control of viruses or global warming (Miller 2006). This is significant because not only are these topics mentioned routinely in news media, but they also underlie some of the major political decisions made by government. If the citizenry is not capable of understanding these concepts, how can they form opinions and contribute to public discussion of these matters? Indeed, one of the advantages of gaining scientific literacy is that the development of specialized knowledge and expertise contributes to lay knowledge as it pertains to controversial issues (Aitken 2009). While Miller (2006) does not know what the right number is for the number of scientifically literate citizenry, he contends that current levels are too low. Miller (1998) emphasizes that the number of public policy decisions requiring civic scientific literacy is expected to increase over the next 50 years, and a literate society will produce individuals who can identify information from a credible source and evaluate multiple perspectives when addressing controversial issues (McBean and Hengeveld 2000).

Regardless of how it is defined or what approach educators use to achieve it, all citizens need some level of scientific literacy. Citizens are becoming increasingly more active in bringing scientific discussions into the public domain. Collins and Evans (2002), in their discussion of the third wave of expertise, require the public to be knowledgeable in order to effectively engage in discussion with scientists and other experts. It is also important to consider who is driving public policy. If less than 30 per cent of the population in Western societies (Miller 2006) is scientifically literate, is this the group actively involved in decision making? Or is it the remaining 70 per cent, who are considered scientifically illiterate, that drive policy? How does this affect the society we live in? Is it socially responsible to have a population that cannot assess and evaluate scientific and socioscientific issues?

Teachers are presented with an ever-growing list of challenges— content, inquiry, nature of science, scientific literacy and social makeup of the class, to name a few. It is currently the responsibility of the curriculum makers to determine what is important to teach. In Alberta, my experience has been that the curriculum is broad enough to encompass many of the above list and allows a certain amount of teacher discretion to determine the approach to take. Most science teachers believe that students need to have a certain level of factual knowledge (Roth and Lee 2004), and I have found that many teachers tend to focus on these content skills at the expense of other areas. At the secondary level, provincial exams drive teachers to focus on content knowledge. Although teachers value the flexibility of the curriculum, without some guidance on how to build scientific literacy, teachers will continue to focus on the content knowledge instead of the application of science.

Final Thoughts

Scientific literacy should be one of the goals of science education. While citizens do not need to have the same level of scientific understanding as scientists and experts, they do require civic or functional scientific literacy in order to operate in today's society. This level of literacy allows citizens to have basic scientific understanding, familiarity with scientific terms and the ability to pick up a newspaper and understand its content. It also gives citizens the opportunity to engage in public discussion of scientific issues. While this represents the most basic level of scientific literacy, it establishes a base from which to build knowledge. As Gross (2006) suggests, people can learn a lot with proper motivation, and socially relevant topics may provide this motivation.

Science education seems like a natural fit for building these skills. However, given current rates of scientific literacy in Western societies, it is apparent that our current models are not working. Numerous strategies exist for building literacy skills but many experts suggest the use of socio-scientific, STS (science, technology and society) or socially relevant issues as being the most effective in classroom instruction. Current curriculum in Alberta includes STS instruction and should be used by teachers to build literacy skills, though teachers may need assistance in developing usable strategies in the classroom.

A society would not tolerate verbal literacy rates as low as current scientific literacy rates, nor would it be able to function. Our society is becoming more focused on science and technology, and we have a responsibility to ensure that the next generation of citizens can understand, evaluate and discuss this knowledge in a meaningful way. Given the role of education in society, the responsibility can and should be ours as educators to develop the scientifically literate citizen.

References

Aitken, M. 2009. "Wind Power Planning Controversies and the Construction of 'Expert' and 'Lay' Knowledges." *Science as Culture* 18, no 1: 47–64.

Bauer, M, N Allum and S Miller. 2007. "What Can We Learn from 25 Years of PUS Survey Research? Liberating and Expanding the Agenda." *Public Understanding of Science* 16, no 1: 79–95.

Brossard, D, and J Shanahan. 2006. "Do They Know What They Read? Building a Scientific Literacy Measurement Instrument Based on Science Media Coverage." *Science Communication* 28, no 1: 47–63.

Collins, H M, and R Evans. 2002. "The Third Wave of Science Studies: Studies of Expertise and Experience." *Social Studies of Science* 32, no 2: 235–96.

Fensham, P. 2002. "Time to Change Drivers for Scientific Literacy." *Canadian Journal of Science, Mathematics and Technology Education* 2, no 1: 9–24.

Fensham, P, and W Harlen. 1999. "School Science and Public Understanding of Science." *International Journal of Science Education* 21, no 7: 755–63.

Gross, L. 2006. "Scientific Illiteracy and the Partisan Takeover of Biology." *PLoS Biology* 4, no 5: 680–83.

Hobson, A. 2001. "Teaching Relevant Science for Scientific Literacy." *Journal of College Science Teaching* 30, no 1: 238–43.

Kolstø, S. 2001. "Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues." *Science Education* 85, no 3: 291–310.

Laugksch, R. 2000. "Scientific Literacy: A Conceptual Overview." *Science Education* 84, no 1: 71–94.

Lee, S, and W M Roth. 2003. "Science and the 'Good Citizen': Community-Based Scientific Literacy." *Science, Technology, and Human Values* 28, no 3: 403–24.

McBean, G, and H Hengeveld, H. 2000. "Communicating the Science of Climate Change: A Mutual Challenge for Science and Educators." *Canadian Journal of Environmental Education* 5, no 1: 9–23.

Miller, J. 1998. "The Measurement of Civic Scientific Literacy." *Public Understanding of Science* 7, no 3: 203–23.

———. 2006. "Civic Scientific Literacy in Europe and the United States." Paper presented to the annual meeting of the World Association for Public Opinion Research, Montreal, Canada, May 16–18.

Moore, A, and J Stilgoe. 2009. "Experts and Anecdotes: The Role of 'Anecdotal Evidence' in Public Scientific Controversies." *Science, Technology, and Human Values* 34, no 5: 654–77.

Roth, W M. 2002. "Taking Science Education Beyond Schooling." *Canadian Journal of Science, Mathematics and Technology Education* 2, no 1: 37–48.

Roth, W M, and J Désautels. 2004. "Educating for Citizenship: Reappraising the Role of Science Education." *Canadian Journal of Science, Mathematics and Technology Education* 4, no 2: 149–68.

Roth, W M, and S Lee. 2004. "Science Education as/for Participation in the Community." *Science Education* 88, no 2: 263–91.

Shen, B S P. 1975. "Science Literacy and the Public Understanding of Science." In *Communication of Scientific Information*, ed S B Day, 44–52. Basel: Karger.

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Nature of Science or Nature of Reality: What Is the Purpose of Science Education?

Monica Chahal

Abstract

The relevance of this analysis to the field of education is unmistakable. The new global education market has placed an increasing reliance on science as means for creating good citizens. My paper is a critical analysis of the discourse of science as a means to increase the skills of a nation. Through it, I hope to provide an arena for discussion of the links between the science curriculums of the United Kingdom and that of Alberta and how this reliance on the perceived reality of science is affecting our students.

How paramount the future is to the present when one is surrounded by children.

—*Charles Darwin*

Any intelligent fool can make things bigger, more complex ... It takes a touch of genius—and a lot of courage—to move in the opposite direction.

—*Albert Einstein*

I contend that the *nature of science* should be called the *nature of reality*; through this statement I will endeavour to unravel the purpose of science education as it currently exists and what it could possibly be. I will define the term *nature of science* and discuss the history and purpose of the science curricula in the United Kingdom and Alberta. Through this discussion I hope to highlight how both curricula perpetuate science as a means to increase human capital (Becker 2006). The source documents for this analysis are the United Kingdom's 1988 *Education Reform Act*, various Qualifications and Curriculum Authority documents and the Alberta program of studies. The relevance of this analysis to the field of education is unmistakable. The new global market has placed an increasing reliance on science as means for enabling students to fulfil their adult roles. Through my paper I hope to provide an arena to discuss the links between the science curriculua of the United Kingdom and Alberta and how this reliance on the perceived reality of science is affecting our students.

What Is the Nature of Science?

Nature is, collectively, the phenomena of the physical world (including plants, animals and landscape) and products of the earth, as opposed to human creations. Meanwhile, science is an intellectual and practical activity that includes the study of the structure and behaviour of the physical and natural world through observation and experiment (http://oxforddictionaries.com/definition/science). Consequently, the *nature of science* can be described as the phenomenon of organizing; it is a way of knowing and framing the world. "Nature of science refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge" (Lederman and Lederman 2004, 36). According to McComas (2004), "nature of science is the sum total of the 'rules of the game' leading to the knowledge production and evaluation of truth claims in the natural sciences" (p 25); thus the creation of boundaries around the subject of science has given science power as a form of knowledge (Gieryn 1983). Science needs a republic (Polanyi, 1964), and the boundaries surrounding this republic create a situation in which the power within the republic dictates the nature of science as reality. The republic consists of scientists that are "cooperating as members of a closely knit organization" (p 54). According to Polanyi, there is an "invisible hand" guiding scientists' work, and that hand is guided by the "scientific merit accepted by the scientific community" (Polanyi 1962, 57); thus, the republic codifies knowledge.

Reality stems from the Latin *realitas* or *realis*, meaning "relating to things" (http://oxforddictionaries.com/definition/reality). Therefore, I define reality as the way students relate to their world, studies, education and, particularly, science; in this paper I have used the words *reality* and *world* interchangeably. Currently, science education is creating an imitation of reality for students; the image that students perceive is not a true representation of the reality of science—science education is constructing a perception of the world as technocratic. Consequently, students are unable either to merge their reality into the lessons or to weave the reality they have been taught into the world as it exists for them; whichever occurs, the creation of a disillusioned student is inevitable.

What Science Is Not

Merton (1938) describes science as objective; this continues to be emphasized within science classrooms, mainly by the use of the scientific method. Something that "excludes subjectivity can never be *whole*" (Park 1996, 4); therefore, the scientific method cannot be considered whole. What we need to incorporate is the understanding that within science the "subjective–objective" needs to be broken. What is considered science and the boundaries that surround science must change in order to create better science for students. Science is subjective; science is collaborative as much as it is a solo endeavour; science is not about method but focused on creativity, discovery and explanations; science has a history and it is culturally and socially influenced (Barrow 2010; Lederman and Lederman 2004; McComas 2004; Reeves, Chessin and Chambless 2007; Roe 1972). Without the inclusion of subjectivity, science as a field of study will never be whole. It will never fully embrace students that look at science with a bias of their own—with their own reality.

History Is Merely a Story

The curriculum is a policy document made of many different facets and often reflective of its context; it must be "read in relation to the time and the particular situation of their production" (Bowe and Ball 1992, 21). Therefore, before I can discuss the science curricula as they exist currently I must address the story of the science curriculum.

United Kingdom

In 1988, the Margaret Thatcher government created the *Education Reform Act* (ERA), widely regarded as the single most important piece of education legislation in England, Wales and Northern Ireland. With the creation of the ERA, economy and educational policy became entwined and this influenced how students were perceived. Some key points in the ERA included introduction of grant-maintained schools, introduction of local management of schools,[1] introduction of the National Curriculum, introduction of Key Stages,[2] creation of explicit educational objectives, the ability of parents to specify which school was their preferred choice (under the concept of a school market), and the creation and implementation of league tables (ie, publication of examination results). With the creation of the national curriculum, science was given an elevated status as one of the few subjects deemed a core subject.

Under the 1988 ERA, the secretary of state became the sole person responsible for the national curriculum and its delivery. In order to aid the secretary of state, two councils were established: the National Curriculum Council and the School Examinations and Assessment Council. These councils, created under the 1988 ERA, reinforced that teachers were no longer responsible for the matter of subject material; content became controlled by the state. The purpose of was to "prepare such pupils for the opportunities, responsibilities and experiences of adult life" (*Education Reform Act* 1988, section 23).

Alberta

At confederation, in 1905, all aspects of education were centralized under the authority of a minister of education (Sheehan 1986). *All aspects* included textbooks, inspectors, examinations, teacher education and certification and, most significantly, the curriculum, the purpose of which was citizen preparation.

Throughout the 1900s there were various changes to education in Alberta, due to multiple reasons such as migration, immigration patterns and high dropout rates. However, "adjustments to the program of studies were not linear" (Sheehan 1986, 40). After the turn of the 20th century, schools became a "vehicle for social reform" (Sheehan 1986, 43), whereby progressive education became the new educational slogan and the formation of the Canadian identity paramount. Through the 1920s, Alberta's schools saw a new, child-centred approach. The fruition of this approach could be seen in 1935, when William Aberhart, a school principal, was elected as premier; in addition to himself as minister of education, his caucus included eleven school teachers. It was during this time that the structure of elementary and high schools and, ultimately, the creation of junior high school were implemented. In elementary schools, group planning and decision-making skills were deemed to be most important, and the subjects focused on were social studies, science and health. In junior high schools, the goal was to gear the education to the students' own aptitudes and skills; science was considered a core subject. In senior high schools, science was considered an elective subject. However, because universities greatly influenced schools and because senior high schools were divided between academic and nonacademic institutions, parents sought out the academic schools in order to secure financial security for their children. These changes to the educational system were the most radical changes to education in the nation at the time. In the 1970s, however, Alberta changed dramatically; a swing to traditionalism resulted. In the 1980s, a prescribed core, with specified content and provincial examinations with specialized diplomas, was implemented.

The notion of a good citizen is prevalent throughout the story of the curricula. Furthermore, throughout the history of both curricula, science as a subject was of particular importance. In today's context, what is a good citizen and how does this affect today's science classroom?

The Current Goal

Although the purpose of the curriculum remains constant, "the curriculum itself cannot remain static. It must be responsive to changes in society and the economy" (Qualifications and Curriculum Authority 2004, 13); the science curriculum needs to evolve to properly respond to societal changes and the emergence of new technologies.

The United Kingdom's 1988 ERA states that the curriculum prepares "pupils for the opportunities, responsibilities and experiences of adult life" (*Education Reform Act* 1988, p 1); the Alberta curriculum in 1972 advocated "a career-orientated approach, one that would make education relevant to the adult role in society" (Sheehan 1986, 49). The focus on adult life/role is, in reality, a focus on preparation for future occupations in order to enhance the economy of the nation. The opportunities created by education are supposed to enable the creation of a responsible adult. Durkheim (1956) believed that education had two main purposes: "the socialization of the young for their future adult roles, and their selection into employment" (p 382). Consequently, the economy provides the public setting in which students become the commodities to fulfil future positions in the job market. According to Yörük, Morgil and Secken (2009), "the development of a country … depends on the reformations in the field of education" (p 65); thus, a country's drive to become an economic power in the global market education is affected.

Globalization, Knowledge Economy and Human Capital

Globalization has created a global market that encompasses smaller nation-state markets within it—what is now referred to as the "global economy" (Brown and Lauder 1996). This has meant a change with regard to competition in the market; a desire to compete successfully in the global economy has led to the commodification of knowledge. The commodities that are bought and sold within this larger market are what is known as human capital (Becker 2006; Taylor 2004). Human capital comprises various different facets of an individual, including "information, ideas, skills, and health" (Becker 2006, 292). This is important—new ideas drive enterprise, create new products and new markets, and improve efficiency, delivering benefits to firms, customers and society. In addition, "world-class science is needed to connect with business, and creating the right mix of incentives and support mechanisms to grow new knowledge" (Her Majesty's Stationery Office 2006, 8). Science is deemed to be the most effective means of investing in the economy, thereby creating a stronger economy. Consequently, to create and maintain a stronger economy, a nation must invest in science education to increase its human capital.

Consequently, the form of education required for students to be economically viable citizens is in the form of skills training (Avis 1996; Brown and Lauder 1996; Gleeson 1996; Gleeson and Keep 2004; Green 1997) because the "the economic future for the country is residing in the skills of its people" (Avis 1996, 74). This sentiment was succinctly stated by Tony Blair:

> Education and training hold the key, not just of personal fulfilment and advancement, but also to economic prosperity and a good society. Investment in education is investment in here-and-now of our children, but it is also investment in the skills and minds of the future which will rebuild our national wealth and social fabric. (1994; cited in Avis 1996, 74)

In the past, the type of skill required was to produce a standardized product using skills unique to a general assembly line (Avis 1996; Brown and Lauder 1996; Gleeson and Keep 2004; Green 1997; Gleeson 1996). The changes in the global market have meant a change to the type of skill needed—the skill now sought is scientific enterprise. Yörük, Morgil and Secken (2009) state that technological and societal demands affect "the way in which science subjects are taught" (p 69), so how is society's need to compete in the global market affecting science education?

United Kingdom

The answer in the United Kingdom is simple: change. The new science curriculum's purpose is to "enable schools to raise standards and help all their learners meet the challenges of life in our fast-changing world" (Qualifications and Curriculum Authority 2007b, 3).

For science, this means making sure that students are ready for the "fast-changing world" and thus "greater engagement, motivation and scientific literacy for all" (Read 2007) for the 21st century. The changes in the science curriculum (the new 21st-century science) will hopefully enable students to "discover how scientific ideas contribute to technological change—affecting industry, business and medicine and improving quality of life (Department for Education Skills and Qualifications and Curriculum Authority 2004, 70); this quote relates directly to the knowledge economy but, most important, it directly links science education with human capital. In order to achieve the goal of creating more human capital there has been an increased focus on scientific thinking, applications and implications of science, cultural understanding and collaboration, communication skills, practical enquiry, and critical understanding of evidence (Qualifications and Curriculum Authority, 2007b). In addition, the *Science and Innovation Investment Framework* document states that science in schools must change because "science in schools was neither encouraging sufficient numbers of students to study science further, nor adequately addressing the science needs of future citizens" (Her Majesty's Stationery Office 2006, 42), thus creating a strong link between globalization and the curriculum.

As highlighted by the quotations above, the reason for change is not to aid students in creating connections between science and their personal world; instead, science education is to increase the nation's economic prosperity.

Alberta

In Alberta, the case is very similar. Historically, the main goal of Alberta's curriculum in the 1900s and into the 1980s was to create a "good citizen"; today this can be interpreted as creating a viable worker.

Canada, like the United Kingdom, is trying to participate in an increasingly global world; instead of creating citizens that compete only in Alberta's economy, we good Canadians need to become global citizens in order to fulfil our adult roles successfully. Today's student must "become scientifically literate, students must develop a thorough knowledge of science and its relationship to technologies and society" (Alberta Education 2005, 1); in Alberta, what appears to be of most concern is knowledge of science in order to aid in the creation of technology that will support Alberta's desire to compete in the global market. In order to compete in this global marketplace, "students graduating from Alberta schools require the scientific and related technological knowledge and skills that will enable them to understand and interpret their world and become productive members of society" (Alberta Education 2005, 1).

As is evident in both curricula, the need for employable individuals in our technologically driven society is paramount. I contend that the governments of both Alberta and the United Kingdom are creating an arrangement in which the education system will generate workers that fulfil the government need for human capital in the new global market. As a result, the subject of science is focused on scientific literacy and critical thinking in order to fulfil the perceived requirements of society. However, does this create a better world for our students? What is the nature of science for students in today's economically driven society? I argue that the nature of science today, apparent in both curricula, continues to place boundaries around science. Finally, does this drive for a technocratic society reflect our students' reality?

The Possibility

I assert that the importance of science today is non-negotiable; science is seen as a means for preparing students for an economic world (Apple 2006; Brown 2003; Hyslop-Margison and Sears 2006). Education should be about aiding in the creation of wise people who in their wisdom are able to aid in the betterment of society; "the whole purpose of society lies in enabling its members to pursue transcendent obligations" (Polanyi 1964, 83). Our students are wise, yet the subject of science is not relevant to them. It is not a part of their reality. It does not build on the wisdom present in their lives or their tacit knowledge. Science does not fit the reality of their world.

Education "is supposed to confer equal status on all citizens, regardless of sex, race, ethnicity, or religion, regardless of whether one is rich or poor. But it does not, as we know do this" (Tupper 2008, 71). What does it say about a system that as students progress, their hopes and dreams become fewer and fewer until their dreams no longer exist? The educational system in both countries is losing students. We are losing brilliant minds—possibly another Darwin or Einstein. Students are disengaged from school science; they do not see participation as important. The reality for educators is that there are a large number of students that are not able to take part in the current educational system. Students in both countries that do not fully participate are streamed into nonacademic routes and deemed unable; I contend that they *are* able—*we* are unable to create a situation in which the students are welcome. Students in Science 14/24[3] (in Alberta) and those who hold a single General Certificate of Secondary Education[4] or the General National Vocational Qualification (GNVQ)[5] (in the United Kingdom) become second-class students in their schools; their choices for future employment and education are severely restricted. If the purpose of a science curriculum is to create more human capital by developing scientifically literate individuals, than the curriculum is failing. Science education should not be creating second-class citizens.

It is imperative to find a methodology that does not fall on one side of the objective–subjective debate. Educators must bring to an end the Mertonian (1938) perception of an unbiased scientific principle. What is essential is a shift; "methodology, if it is to disclose reality, must be adapted to the nature of reality; otherwise it becomes tyrannical" (Park 2009, 5). The scientific method does not address the reality of the children it is directed towards nor does it build on their tacit knowledge. Science as it stands has become a tyranny. It oppresses those that do not fit its predetermined view of the world and the oppressed are eventually weeded out by failure and removal from the educational realm of science. The difficulty is that those "who limit themselves to a preconceived method of studying reality do not thereby determine the nature of reality" (Park 1996, 5); however, in the realm of science educators, scholars and academics determine the nature of science as the nature of reality. What they perceive to be scientifically relevant is what is taught to students as the truth about science. The question I see is what reality do we, as educators, want to create for our students?

I do not want students to feel that they must belong to a predetermined culture of science; I want them to realize that science is everywhere and not just in the classroom. It is imperative that science should not be seen as "how it differs from other ways of knowing" (Reeves, Chessin and Chambless 2007, 32), as this perpetuates the framing of science as merely a type of knowledge. Instead, as students discover the nature of science, I hope that they realize that science is in actuality the nature of reality; it is literally unsystematic, disorganized, chaotic and clumsy. Science is messy and fun. Science is about breaking preconceived ideas. Simply put, science is about the possibility. That is the truth behind science, and that is the reality I want for all future science students. This can be done only by bringing students into science and not forcing the prescribed curriculum of science onto them.

In Closing

The discourse surrounding the science curriculum is focused on the need to create a viable and flexible work force. Learning the mandated science curriculum enables a person to become a productive worker in today's global world. What is essential now is not creating individuals that are able to freely express themselves, but constructing a system that will produce a labour force, thus producing human capital for the knowledge economy. However, what is being left out is that not all students will have the same options in this market. Therefore, instead of enabling all students to participate in education equally, a two-tiered system is created and second-class citizens are produced. I argue that if the nature of science was to be referred to instead as the nature of reality, the focus would shift from creating a work force to creating connections. Students would be able to connect the science in the classroom to their own world and, in doing so, would create associations that last far beyond the classroom doors. Students would then begin to understand the true nature of science—collaborative, muddled, disordered, cluttered and fascinating. Students would see that science *is* reality.

Notes

1 Financial control was handed to the head teacher and the governors of a school.

2 Key Stage 1 year (grade) 1–3, Key Stage 2 year (grade) 4–6, Key Stage 3 year (grade) 7–9, Key Stage 4 year (grade) 10 and 11, Key Stage 5 year (grade) 12 and 13.

3 In Alberta, Science 14 and 24 satisfy the general requirements for science high school diploma. They are activity-based courses.

4 In the United Kingdom, GCSE is an academic qualification awarded in a specific subject. In order to pursue a postsecondary education route, students must have at least a double GCSE in science.

5 In the United Kingdom, GNVQ is a vocational course offered only in nonacademic secondary institutions. For many higher education institutions, it is not recognized as a valid science grade.

References

Alberta Education. 2005. *Science 10.* Edmonton, Alta: Alberta Education.

Apple, M. 2006. "Producing Inequalities: Neo-Liberalism, Neo-Conservatism, and the Politics of Educational Reform." In *Education, Globalization and Social Change*, ed H Lauder, P Brown, J Dillabough and A Halsey, 468–89. Oxford: Oxford University Press.

Avis, J. 1996. "The Myth of the Post-Fordist Society." In *Knowledge and Nationhood: Education, Politics and Work*, ed J Avis, M Bloomer, G Esland, D Gleeson and P Hodkinson, 71–82. London: Cassell.

Barrow, L. 2010. "Encouraging Creativity with Scientific Inquiry." *Creative Education* 1, no 1: 1–16.

Becker, G S. 2006. "The Age of Human Capital." In *Education, Globalization and Social Change*, ed H Lauder, P Brown, J Dillabough and A Halsey, 292–94. Oxford: Oxford University Press.

Bowe, R, and S J Ball. 1992. *Reforming Education and Changing Schools*. London: Routledge.

Brown, P. 2006. "The Opportunity Trap." In *Education, Globalization and Social Change*, ed H Lauder, P Brown, J Dillabough and A Halsey, 381–97. Oxford: Oxford University Press.

Brown, P, and H Lauder. 1996. "Education, Globalization and Economic Development." *Journal of Education Policy* 11, no 1: 1–25.

Department for Education Skills, and Qualifications and Curriculum Authority. 2004. *The National Curriculum. Handbook for Secondary Teachers in England, Key Stages 3 and 4*. London: Her Majesty's Stationery Office.

Durkheim, E. 2006." Education: Its Nature and Its Role." In *Education, Globalization and Social Change*, ed H Lauder, P Brown, J Dillabough and A Halsey, 76–87. Oxford: Oxford University Press.

Gieryn, T F. 1983. "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists." *American Sociological Review* 48, no 6: 781–95.

Gleeson, D. 1996. "Post-Compulsory Education in a Post-Industrial and Post-Modern Age." In *Knowledge and Nationhood: Education, Politics and Work*, ed J Avis, M Bloomer, G Esland, D Gleeson and P Hodkinson, 83–104. London: Cassell.

Gleeson, D, and E Keep. 2004. "Voice Without Accountability: The Changing Relationship Between Employers, the State and Education in England." *Oxford Review of Education* 30, no 1: 37–63.

Green, A. 2006. "Education, Globalization and the Nation State." In *Education, Globalization and Social Change*, ed H Lauder, P Brown, J Dillabough and A Halsey, 192–97. Oxford: Oxford University Press.

Her Majesty's Stationery Office. 2006. *Science and Innovation Investment Framework 2004–2014: Next Steps*. London: Her Majesty's Stationery Office.

Hyslop-Margison, E, and A Sears. 2006. *Neo-Liberalism, Globalization and Human Capital Learning. Reclaiming Education for Democratic Citizenship*. Dordrecht, Netherlands: Springer.

Lederman, N, and J Lederman. 2004. "Revising Instruction to Teach Nature of Science." *Science Teacher* 71, no 9: 36–39.

McComas, W. 2004. "Keys to Teaching the Nature of Science." *Science Teacher* 71, no 9: 24–27.

Merton, R K. 1938. "Science and the Social Order." *Philosophy of Science* 5, no 3: 321–37.

Mitroff, I I. 1974. "Norms and Counter-Norms in a Select Group of Apollo Moon Scientists: A Case Study of the Ambivalence of Scientists." *American Sociological Review* 39: 579–95.

Park, O. 1996. *An Invitation to Dialogue Between East and West: A Critique of the Modern and the Post-Modern Thought*. New York: Peter Lang.

Polanyi, M. 1962. "The Republic of Science: Its Political and Economic Theory." *Minerva* 1: 54–74.

———. 1964. *Science, Faith and Society: A Searching Examination of the Meaning and Nature of Scientific Inquiry.* Chicago, Ill: University of Chicago Press. Orig pub 1946.

Qualifications and Curriculum Authority. 2004. *The National Curriculum Handbook for Secondary Teachers in England*. London: Her Majesty's Stationery Office.

———. 2007a. *The New Secondary Curriculum: What Has Changed and Why*? London: Her Majesty's Stationery Office.

———. 2007b. *Science Programme of Study for Key Stage 3 and Attainment Targets*. London: Her Majesty's Stationery Office.

Read, D. 2007. "Changes in Schools and Their Impact: Perspectives from Both Sides of the Divide." Lecture notes. London: Institute of Education.

Reeves, C, D Chessin and M Chambless. 2007. "Nurturing the Nature of Science." *Science Teacher* 74, no 8: 31–35.

Roe, A. 1972. "Patterns in Productivity of Scientists." *Science* 176, no 4037: 940–41.

Sheehan, N M. 1986. "Education, the Society and the Curriculum in Alberta, 1905–1980: An Overview." In *Schools in the West: Essays in Canadian Educational History*, ed N M Sheehan, J D Wilson and D C Jones. Calgary, Alta: Detselig.

Taylor, S. 2004. "Researching Educational Policy and Change in 'New Times': Using Critical Discourse Analysis." *Journal of Education Policy* 19, no 4: 433–51.

Tupper, J A. 2008. "Feminism Confronts Democracy: Challenging Universal Citizenship and Democratic Education." In *Decolonizing Democratic Education*, ed A Abdi and G Richardson, 67–76. Rotterdam: Sense.

Yörük, N, I Morgil and N Secken. 2009. "The Effects of Science, Technology, Society and Environment (STSE) Education on Students' Career Planning." *US–China Education Review* 6, no 8: 68–75.

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Usefulness of Nature of Science, Socioscientific Issues and Argumentation in Achieving Scientific Literacy

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In my experience, students continually question why they need to learn certain things or complain about how boring science facts are. Lack of relevance and engagement is an obstacle to achieving scientific literacy in today's classrooms. This is a problem if the goal of science education is to produce a scientifically literate citizen. The question for teachers, then, is how can we overcome these obstacles? Scientific literacy is complex and has been described in many ways, as noted by Bell and Lederman (2003). I characterize scientific literacy as "including understandings of science content, scientific methods of inquiry, and the nature of science" (Bell and Lederman 2003, 370). Of the characteristics mentioned, the one that is often overlooked yet crucial to achieving scientific literacy is *nature of science* (NOS). The current Alberta science curriculum adequately addresses the areas of scientific methods of inquiry and science content; however, these concepts are approached using the traditional method of memorization of facts, theories and laws in a noncontextualized manner. As a result, students do not feel connected or engaged with the science they are learning. I propose that by incorporating a different approach we can increase student engagement and thus produce citizens who are capable of making decisions in a democratic society involving socioscientific issues (SSI). Borrowing Bell and Lederman's (2003) idea that students can learn to make better decisions regarding science- and technology-based issues if they are taught to apply the nature of science to their decision making, I propose that explicit instruction on how to use current views of the nature of science in decision making be incorporated into classroom instruction. Approaching NOS as a way of knowing creates a problem in that it can be interpreted in a number of ways. In this paper I interpret it as "the values and assumptions inherent to scientific knowledge and the development of scientific knowledge" (Lederman and Lederman 2004, 36). Along with learning about the NOS, students must also learn to use this understanding of NOS in making decisions on controversial scientific issues.

Along with teaching NOS, teachers should incorporate SSIs and argumentation into their teaching practices to present the material in a more natural social context and help students understand issues that may affect them. Contrary to the stereotype of the scientist working alone in a lab, science is far from an individualistic endeavour—it is communal.

Molinatti, Girault and Hammond (2010) proposed an SSI perspective for teaching science that incorporates not only SSI and NOS, but also argumentation as a means of teaching SSI and NOS. In their study, in which experts were used to present information to students, it was concluded that providing only one type of expertise is insufficient. Better results were achieved when different viewpoints and different types of expertise were used. This conclusion ties in with the "third wave" of science studies (Collins and Evans 2002). With the third wave, the role of the classroom teacher is altered from an expert to that of a translator who, due to interactional expertise, has "a special ability to take on the position of the other, and to alternate between different social worlds and translate between them" (Collins and Evans 2002, 258). Students' main two social worlds are home and school. If science is to be meaningful to future generations the curriculum must better reflect the students' social worlds.

Scientific Literacy

My students are representative of the majority of the public, who do not attain scientific literacy. The fact that most citizens remain scientifically illiterate is a strong argument for moving away from the traditional model of teaching science. The focus needs to shift to reflect the social aspects of science and decision-making skills concerning socioscientific and technological issues. The traditional model of teaching science has been prevalent for more than 30 years in most secondary classrooms in Alberta, despite evidence that it is not working. Educators have been talking for some time about scientific literacy, yet nothing changes. Why?

I asked a number of my teaching colleagues, only some of whom are science teachers, what they think the term *scientific literacy* means. It was not surprising that the non-science teachers defined it as the ability to read scientific writing and understand scientific terminology. What was interesting is that all the science teachers to whom I asked this question gave the same reply. The term *literacy* seems to transcend any single course to take on a broad meaning of ability to read and write. I believe that the definition of scientific literacy that is more appropriate would be *a person's knowledge of a particular subject or field that is related to NOS*. What primary literature says scientific literacy is and what teachers understand it to be are miles apart. While teachers believe that scientific literacy means reading and writing in a scientific way, educational scholars view scientific literacy as something that goes beyond reading and writing for scientific purposes. This discrepancy between educators and the academic community concerning the term *scientific literacy* is preventing a significant change in the curriculum and a movement away from the traditional teaching models.

What do scholars say scientific literacy means? Feinstein (2010) examines what he considers to be two parts to scientific literacy, the "good to know" and "usefulness." It is not adequate to say that science is useful—it must be made clear how or why it is useful. I believe the word *engagement* acts as a bridge that allows students to move with greater ease between their social world and that of the classroom. By moving familiar social objects into the classroom and attaching scientific concepts to them, students can transfer these ideas back out of the classroom to their everyday lives. If students find something useful, they are more likely to engage with it in meaningful ways. In other words, what is problematic in their social lives can be brought into the classroom and what is discovered in the classroom can be transferred into their social world. This opens up the possibilities of dialogue, both in the classroom and at home.

To achieve this type of student engagement, educators must start with real-life problems and work backwards, thus determining what science is most useful in solving current problems. This approach uses SSIs at both local and global levels to engage students in scientific processes and relies on external information, which suggests that "scientific literacy is a collective praxis: something that a group of people do or accomplish, particularly when working together on shared projects or overlapping interests" (Feinstein 2010, 174). Norris (1995) refers to this as "intellectual communalism," in which judging science is based on trust, values, morals and beliefs rather than on analysis of data that is beyond the scope of the nonscientific public. Students cannot directly judge data or evidence related to a claim, but they can make decisions about scientific and technological issues by judging other aspects of the information presented. These judgments often rely on trustworthiness. Students need to learn how to decide who to trust and what it means to trust in science. This can be problematic, in that the students are told to trust the teacher and thus will often blindly trust those whom the teacher trusts. Though this may be a starting point, it cannot be the end goal. Students should learn to judge the actions of individuals and groups that make up the scientific community, based on external sources. This cannot be taught if students are taught only science that has been settled within the scientific community. However, the science that students experience in society, usually through the media, is shrouded in controversy and far from neatly settled. This disconnect between school science and real-world science creates mistrust and confusion. Donovan-White (2006) attributes the mistrust of science to the way science is taught as rational, objective, authoritative and free of cultural influences. This implies that today's curriculum and traditional teaching practices are not only not teaching students useful science, but are creating a society that is incapable of making decisions regarding SSIs. This lack of trust is preventing citizens from meaningfully participating in a democratic society.

Students must "gain insights and knowledge that prepares them for doing their own evaluations as to the relative relevance and trustworthiness of different knowledge claims with a science dimension" (Kolstø 2001, 307). This includes different aspects of NOS. By explicitly teaching students about the NOS, teachers will help students develop the ability to make judgments. This method of teaching science calls for students to have a personal connection to the topic, because decision making incorporates values and morals to arrive at a final personal opinion. This personal connection relates to the notion of usefulness, which implies using SSIs that are currently affecting students' lives. In my experience teaching a group of highly disinterested students who do not view science as useful to them, I found Basu and Barton's findings (2007) encouraging. They noted that at-risk youth who took part in the study "felt that useful science was science that could be applied to the things students cared about everyday" (Feinstein 2010, 176). It appears that there is a need to incorporate students' social lives into the classroom as a means of making science useful. Holbrook and Rannikmae's (2007) idea of "education through science" rather than "science through education" calls for a more multidimensional approach to scientific literacy than is currently being applied. This approach links the nature of science, the personal domain and the social domain through activity theory.

There is more to learning science than facts, theories and laws. Science is a social construct, and therefore "the promotion of scientific literacy has become an important goal for science education, and the ability to negotiate socioscientific issues is at least one aspect of scientific literacy" (Sadler 2002, 3). There is a moral aspect to how SSI influences decision-making. Scientific literacy is more than reading and writing—it is the amalgamation of scientific knowledge in the context of social values and beliefs as they apply to people's daily lives.

Socioscientific Issues

Today's curriculum and teaching methods focus on teaching facts, formulas, theories and laws. If time permits, teachers will select an SSI that they feel fits with the material the students have learned and ask students to draw conclusions based on what they learned. Students who are able to transfer what they learn to the issue the teacher has selected do well; students who are not able to make this transition do poorly and conclude that they cannot do science. SSIs are often considered secondary to learning science and are presented from the teacher's or the curriculum's point of view, leaving the students out of the decision-making process. In this scenario, expertise is filtered through the final expert—the teacher—and students are expected to agree with the conclusions of others. Many think that this hierarchical model, though efficient, lacks usefulness for the students. What is called for is a more student-centred approach, in which usefulness takes on a local and personal nature. Teachers need to decide which issues are important in the context of their classrooms. Equally important is understanding that decision making falls within the social domain; it is not simply based on scientific facts as presented by experts, but also draws upon the individual political, religious, moral and personal experiences that constitute a person's value system. Values become an intrinsic part of science. Sadler (2004) believes that

> Socioscientific issues are not the only way of promoting scientific literacy, but they can provide powerful vehicle for teachers to help stimulate the intellectual and social growth of their students. If we want students to think for themselves, then they need opportunities to engage in informal reasoning, including the contemplation of evidence and data, and express themselves through argumentation. (p 533)

SSIs can provide a bridge for students between their social world and the world of the classroom. SSIs allow students to find relevance in science by making what they are learning useful in the context of their everyday lives.

Nature of Science

Another aspect of scientific literacy research focuses on the implementation and teaching of the NOS. Currently, science is taught as a body of knowledge and a set of methods and processes with little regard for *how* we know. The view of science as elitist and rigid is problematic in that it gives students an incorrect picture of what science really is. The science taught in schools does not match the science that occurs in research labs. "Scientists *do* science, while students *learn* science, but what scientists do and students learn in the name of science is not the same thing" (Sharma and Anderson 2009, 1253). Students learn facts and concepts, while scientists, who are scientifically literate, are concerned with the usefulness of science. As Donovan-White (2006) says, "basic scientific concepts provide a framework [but] ultimately, the goal of teaching the Nature of Science (NOS) is to produce scientifically literate students and citizens" (p 2).

Nuangchalerm (2010) states that "scientific literacy is commonly implied as an appreciation of the nature, aims, and general limitations of science coupled with some understanding of the more important scientific ideas" (p 34). It is important for students to understand how NOS relates to their own culture. Culture consists of the values and beliefs a group of people hold and the SSIs that affect them. Students need to develop the ability to think critically about science and to deal with scientific expertise if they are to understand the NOS. Because SSIs have moral and ethical implications, the teaching of scientific literacy also requires attention to moral and ethical implications. Students naturally tend to base their decisions on personal values, morals, ethics and social concerns; this natural tendency needs to be fostered. However, in today's classrooms the prevalent values that are expressed are those of the teacher. The curriculum indicates what topics are to be covered, and teachers select the material to be learned and often provide the conclusions that are to be drawn from what is being taught. Students are required to assimilate the information they are given and apply it to a broader context; however, if the students are to achieve a good mark, they need to interpret the information and make a decision that is in line with that of the teacher. Students whose culture or social structure is different from the teacher tend to do poorly in class, not because they do not have a valid opinion but because it is different from the normative opinion and they lack the skills to argue the validity of their decisions. Part of the inability to formulate a solid argument is that students view the teacher as the final expert. "Current conceptualizations of good science teaching hinge upon the conviction that the teacher should possess knowledge of subject matter, teaching methods, and children" (Osborne 1998, 427). Society trusts the teacher's expertise. Therefore, when presented with conflicting evidence, students usually look to the teacher to settle the debate and choose which expert to believe based on what the teacher says.

Teachers continue to rely on this traditional educational model for two main reasons: incorporating numerous types of expertise in the classroom is time consuming and difficult, and how do you assess students if they all have different answers? Incorporating different expertise is a daunting task; however, if teachers are provided with adequate training and support, this can be accomplished. "Educators … must seek to become current in the related science through improved access to current and credible information, and they must foster an environment of critical thinking amongst students when confronted with conflicting and confusing scientific arguments" (McBean and Hengeveld 2000, 23). With the assistance of social media and science blogs, students and teachers can access many different types of expertise. With explicit instruction in NOS, students would learn how to judge conflicting information based on their own values and beliefs. The issue of assessment can be addressed by using argumentation. Having students not only make a decision regarding an SSI but also defend their decision to their peers and the public not only allows a means of assessment but brings what they are learning into the context of society.

Argumentation

Just as SSIs can be an important in teaching science, so can argumentation. In promoting scientific literacy in education by incorporating SSIs and explicitly teaching NOS, assessment becomes an issue. Kolstø (2001) states that it is necessary to draw a distinction between "science-in-the-making" and "ready-made-science" and the role argumentation plays in the scientific community in finally reaching a consensus among experts. Argumentation is not bullying others into accepting your conclusion, but a give-and-take dialogue that uses reason, logic and empathy to make a point. Molinatti, Girault and Hammond (2010) and Osborne, Erduran and Simon (2004) studied the use of argumentation and debate in the classroom. Both concluded that there was no significant benefit, but pointed out that argumentation is difficult to teach and more long-term study is needed. If students are taught the skill of argumentation from a young age, argumentation can be used as a tool to assess students' mastery of scientific literacy. In my experience, most students are capable of stating their opinion about an SSI, but lack the skill to be able to justify their decision. Lave and Wenger

(1991) state that “Argumentation can transform idealized notions of science classrooms from repositories of science facts to environments that foster legitimate peripheral participation” (cited in Nuangchalerm 2010, 36).

Science educators should bring communities together in ongoing discourse that uses their collective knowledge and expertise, demonstrating that ideas are shaped through conversations among social groups and knowledge is pooled. Learning the skill of argumentation will help students participate in such conversations. The focus should not be on who is the expert, but rather on the dialogue and engaging the students in two-way communication. It is not expertise that is important, but respect and trust of the lay audience. Engagement will make the uninterested interested.

The problem in education becomes one of how to facilitate democratic conversation among students with different backgrounds who are intertwined in an urban school setting. Science blogs and other social media may be the answer. Through blogs and social media sites, lay people and experts alike can pool their knowledge and present different sides of an issue. It is important to explicitly teach students the skill of argumentation so they, too, can have a voice regarding SSIs. Citizens need to be able to sort through conflicting evidence to make a decision and to verbally defend their decisions in a public forum.

Conclusion

The Alberta secondary science curriculum contains terminology such as *scientific literacy* and *nature of science* but presents them in a way that causes them to be misinterpreted or ignored by classroom teachers. Hipkins, Barker and Bolstad (2005) point out that there continues to be a “mismatch between curriculum reform rhetoric in science education and actual classroom practice” (p 243). This discrepancy is likely based on the fact that there is no consensus on what exactly is meant by NOS and, as a result, many teachers believe that they are teaching NOS by following the scientific method or the science–technology–society framework. Teachers are generally not able to teach NOS in their classrooms because they are not given the professional development required to understand what it means. This results in the absence of explicit instruction about NOS, and students are not able to go beyond the view of science as settled, rigid and elite. A solution may be to use extended investigations that the students will see as authentic; this implies an SSI approach.

If the goal of scientific literacy is to be realized in the classroom, the curriculum needs to change to incorporate the true meaning of scientific literacy. The emphasis on facts, theories and laws needs to give way to more open-ended discussions about socioscientific issues, with explicit instruction in the areas of nature of science and argumentation as instructional tools. Furthermore, if educational institutions are to produce a well-informed, responsible citizenry capable of making decisions on SSIs that affect their lives, then what should today’s classrooms look like? Science education should strive to enable students to use scientific knowledge and scientific ways of thinking for personal and social purposes rather than trying to create scientific experts. Scientific literacy is not just for the elite, but for all citizens—we are all called upon to make decisions about SSIs at some point. What we must understand is that the majority of the public will not become scientists or even acquire experience in many scientific and technological areas. Therefore, rather than producing marginal insiders, we should strive to create competent outsiders whose interactions are not those of the researcher or evaluator of evidence but rather the voice in the public and political sphere who participates in determining the direction society takes.

Rather than focusing on science that is considered settled, teachers can introduce issues that have not been settled by the scientific community. Relating such issues to a local perspective would create more relevance for the students and increase their engagement with science. This new curriculum would create competent outsiders rather than marginal insiders—a better-prepared public that is engaged with science—who could make value judgments about technoscientific issues that affect society.

Both NOS and argumentation need to be taught explicitly in the science classroom. Using group work and argumentation, students can learn to evaluate information presented by different experts and judge its trustworthiness based not only on their personal values but on its scientific merit. What a number of the cited references agreed upon is that NOS and argumentation should be explicitly taught in the science classroom; however, the current Alberta science curriculums mention scientific literacy but continue to emphasize traditional facts, theories and laws.

Scientific literacy is often treated as something to cover if time permits. If science is to have a positive, long-lasting effect on students, it must be seen as useful. Feinstein (2010) believes "the idea that science is not inevitably a part of daily life and only becomes so when people see it as useful in light of their pre-existing commitments and motivations" (p 176). It is this relevance that students demand when they ask, "Why are we learning this? It's not like I'm ever going to use it." Perhaps not, but isn't it just good to know?

References

Basu, S J, and A C Barton. 2007. "Developing a Sustained Interest in Science Among Urban Minority Youth." *Journal of Research in Science Teaching* 44, no 3: 466–89. Cited in Feinstein 2010.

Bell, R L, and N G Lederman. 2003. "Understandings of the Nature of Science and Decision Making on Science and Technology Based Issues." *Science Education* 87, no 3: 352–77.

Collins, H M, and R Evans. 2002. "The Third Wave of Science Studies: Studies of Expertise and Experience." *Social Studies of Science* 32, no 2: 235–96.

Donovan-White, C. 2006. "Teaching the Nature of Science." *Atlantic Canada Association of Science Educators Journal (ACASEJAEESA)* 1, no 7: 1–24.

Feinstein, N. 2010. "Salvaging Science Literacy." *Science Education* 95, no 1: 169–85

Hipkins, R, M Barker and R Bolstad. 2005. "Teaching the 'Nature of Science': Modest Adaptations or Radical Reconceptions?" *International Journal of Science Education* 27, no 2: 243–54.

Holbrook, J and M Rannikmae. 2007. "The Nature of Science Education for Enhancing Scientific Literacy." *International Journal of Science Education* 29, no 11: 1347–62.

Kolstø, S. 2001. "Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues." *Science Education* 85, no 3: 291–310.

Lave, J, and E Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press. Cited in Nuangchalerm 2010, 36.

Lederman, N G, and J S Lederman. 2004. "Revising Instruction to Teach Nature of Science." *Science Teacher* 71, no 9: 36–39.

McBean, G A, and G H Hengeveld. 2000. "Communicating the Science of Climate Change: A Mutual Challenge for Scientists and Educators." *Canadian Journal of Environmental Education* 5, no 1: 9–23.

Molinatti, G, Y Girault and C Hammond. (2010). "High School Students Debate the Use of Embryonic Stem Cells: The Influence of Context on Decision-Making." *International Journal of Science Education* 32, no 16: 2235–51.

Norris, S P. 1995. "Learning to Live with Scientific Expertise: Toward a Theory of Intellectual Communalism for Guiding Science Teaching." *Science Education* 79, no 2: 201–17.

Nuangchalerm, P. 2010. "Engaging Students to Perceive Nature of Science Through Socioscientific Issues-Based Instruction." *European Journal of Social Sciences* 13, no 1: 34–37.

Osborne, J, S Erduran and S Simon. 2004. "Enhancing the Quality of Argumentation in School Science." *Journal of Research in Science Teaching* 41, no 10: 994–1020.

Osborne, M D. 1998. "Teacher as Knower and Learner: Reflections on Situated Knowledge in Science Teaching." *Journal of Research in Science Teaching* 35, no 4: 427–39.

Sadler, T D. 2002. "Socioscientific Issues and the Affective Domain: Scientific Literacy's Missing Link." Paper presented at the Annual Meeting of the Southeastern Association for the Education of Teachers in Science. Kennesaw, Ga, nd.

———. 2004. "Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research." *Journal of Research in Science Teaching* 41, no 5: 513–36.

Sharma, A, and C W Anderson. 2009. "Recontextualization of Science from Lab to School: Implications for Science Literacy." *Science and Education* 18, no 9: 1253–75.

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Who Are These Scientist People Anyway? Student Images of Scientists and Ways to Broaden Them

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Abstract

Since World War II, government, business and industry have been focused on the production of scientists to ensure national competitiveness in an increasingly interconnected, global planet. Because K–12 education is seen as foundational in the development of highly qualified people, such as scientists, a good deal of research has focused on how students understand both science and the scientist. The underlying thought in this research seems to be that if students do not know who scientists are, or what they do—or worse, if they have negative perceptions of who scientists are and what they do, they are unlikely to pursue science and become scientists themselves. This paper traces a history of student understanding of scientists and the construct of scientist from World War II to the present, and provides some suggestions about how teachers might bring science to life in the classroom by helping students come to know the people who practice it.

> [Ellie] found a way to make rubies with lanthanide impurities in addition to the chromium atoms, so a maser could be tuned to a narrower frequency range and could detect a much weaker signal than previous masers. Her detector had to be immersed in liquid helium. She then installed her new instrument on one of Cal Tech's radio telescopes in Owens Valley and detected, at entirely new frequencies, what astronomers call the three-degree black-body background radiation—the remnant in the radio spectrum of the immense explosion that began this universe, the Big Bang.
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> …
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> It was necessary to make rubies in large batches, because only a few would have the requisite properties. None were quite of gemstone quality, and most were tiny. But she took to wearing a few of the larger remnants. They matched her dark coloring well.
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> …
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> She would explain to nonscientist friends that she liked rubies but couldn't afford them. It was a little like the scientist who first discovered the biochemical pathway of green plant photosynthesis, and who forever after wore pine needles or a sprig of parsley in his lapel. Colleagues, their respect for her growing, considered it a minor idiosyncrasy. (Sagan 1985, 31–32)

Carl Sagan's novel, *Contact* (1985), focuses on humankind's first encounter with intelligence from beyond Earth through the life of Eleanor (Ellie) Arroway. Readers meet Ellie at birth and come to know her as a fully human person who chooses a career in radio astronomy, not just because of a seemingly innate ability and fascination with existence, but also to spite her misogynist, academic physicist stepfather. While he is the embodiment of the stereotypical scientist who cannot break those bounds, Ellie embodies the complexities of being alive: struggling with the boundaries between science and religion, revelling in night-time drives through the New Mexico desert, wearing rubies created in her lab and scrambling her way to the top of a highly competitive field.

I read Sagan's novel about once a year, not only for the story, but because I know and admire Ellie. I have met her on more than one occasion, as both man and woman, in various fields in the pure and applied sciences. Unlike many representations of the scientist, Ellie has verisimilitude; she is recognizable as the people I have come to know as scientists. Of course, I grew up around people who practiced science for a living, and I have spent a large part of my career working directly with scientists and engineers. I know from this experience that scientists laugh, cry, play sports, engage in art, get caught up in petty jealousies, love their families, etc—that they are, in other words, fully human and engaged in science as a human activity. However, research strongly suggests that I am in the minority, and that the perceptions and images most young people (and many adults) have of scientists are not those of complex human beings involved in a human activity of coming to understand the world.

Lemke (1993) suggests that

> Most students, in the course of ten or more years of what is called "science education" in school, never meet a scientist, never observe science being done in the laboratory or the workplace, never see samples of professional scientific or technical writing, never hear the language of science in use for its normal social functions, never come into contact with the equipment, processes, practices, and social and economic realities of science as a human activity.

So how do students come to know who scientists are? How do we know? Why do we care? And why are the answers to any of these questions important in science classrooms? This paper examines these questions by tracing a history of understanding of scientists and the construct of scientist from World War II to the present and looking at how we might more effectively bring science to life in the classroom by helping students come to know the people who practise it.

Globalization and a Growing Interest in Science and Scientists

Research about scientists, or at least the construct of scientist, seems to have paralleled government and business/industrial interests in and growing reliance on science as a competitive advantage in military operations, exploration, national intellectual capital and/or economics. Beginning around the time of World War II, researchers began to examine the role of the scientist, the work of the scientist and the psychological makeup of the scientist (Merton 1973; Polanyi 1964; Roe 1961)—perhaps not surprising, given the role that science and technology played in helping to determine the outcome of that conflict. In the aftermath of World War II and the growing Cold War between Western democracies and communist Soviet nations, science was also seen as key to survival in the growing arms and space races. The ability to produce adequate numbers of highly qualified scientists became a national imperative in a number of countries, and it was at this point that study on student perceptions, conceptions and images of science and scientist began. The underlying thought in some of this early work seems to have been that if students do not know what scientists are, or what they do—or worse, if they have negative perceptions of what scientists are and what they do, they are unlikely to pursue science and become scientists themselves.

While the major impetus for the production of scientists has largely shifted from the need for military superiority to that of international economic competiveness in knowledge-based global markets, not much else has changed. The Government of Alberta has stated that success in this kind of economy depends on building a community of highly qualified people (Alberta Advanced Education and Technology 2008a) and that education is key in the development of such a community (Alberta Advanced Education and Technology 2008b).

Finding Out How Young People Imagine Scientists

In 1957, the American Association for the Advancement of Science (AAAS) tasked anthropologists Margaret Mead and Rhoda Métraux with determining how high school students imagined scientists (Mead and Métraux 1957). Their study showed that

> while an official image of the scientist … has been built up which is very positive, that is not so when the student's personal choices are involved. Science in general is represented as a good thing … However, when the question becomes one of personal contact with science, as a career choice …, the image is overwhelmingly negative. (p 384)

This conclusion was reached through a survey of 35,000 students from all over the United States. The survey consisted of three essay questions that sought students' images and perceptions of scientist. From the gathered data, researchers developed a composite image of the scientist held by students.

> The scientist is a man who wears a white coat and works in a laboratory. He is elderly or middle aged and wears glasses. He is small, sometimes small and stout, or tall and thin. He may be bald. He may wear a beard, may be unshaven and unkempt. He may be stooped and tired.
>
> He is surrounded by equipment: test tubes, Bunsen burners, flasks and bottles, a jungle gym of blown glass tubes and weird machines with dials. The sparkling white laboratory is full of sounds: the bubbling of liquids in test tubes and flasks, the squeaks and squeals of laboratory animals, the muttering voice of the scientist. (pp 386–87).

Sound familiar? Despite being more than 50 years old, this description still serves as a baseline for research regarding people's images, constructions, perceptions and conceptions of scientists, and is frequently cited. Moreover, it has been used to inform the development of a number of instruments that teachers may have used or seen used in their classrooms such as the Draw-A-Scientist test (DAST) (Chambers 1983) or the Image of Science and Scientist scale (Krajkovich and Smith 1982). These tests, particularly the DAST (and the related DAST-C), are easy to administer and allow for large sample sizes (Schibeci 2006). DAST and variations on it are widely used because, as image-based tests, they provide means of examining images and perceptions of very young children and allow for testing across language groups (Chambers 1983). Results over time have shown the composite image uncovered by Mead and Métraux (1957) to be remarkably persistent and resilient across grade levels, gender, race and national borders (Finson 2002; Schibeci 2006). The stereotype of scientist appears to take hold in the middle elementary years (Buldu 2006) and, without some type of intervention or personal experience of science and scientist, persist into adulthood (Bovina and Dragul'skaia 2008; Song and Kim 1999).

Studies conducted over the last 15 to 20 years have shown some shift away from the male stereotype by young women, although overall it seems that scientists are still perceived to be men (Ramsay, Logan and Skamp 2005). There have been some indications of small increases in the percentage of non-Caucasian children drawing non-Caucasian scientists (Sumrall 1995), but again the perception of scientist does appear to be primarily white. Some differences in the image appear to emerge across culture or context. For example, Monhardt (2003) demonstrated that Navajo students often drew scientists working outside and drew an almost equal number of male and female scientists. She speculated that these differences were connected to culture and indicated the importance of place in Navajo understanding and experience of the world as well as the traditionally matriarchal structure of the community.

Source(s) of the Image: The Need to Dig Deeper

In fact, until recently, explanations regarding the shifts and differences demonstrated above were largely speculative. One of the drawbacks of DAST and similar tests is that, in and of themselves, they do not provide any information about why students have drawn or answered questions in the manner in which they have. The weakness was alluded to more than 25 years ago (Chambers 1983), but explicit calls to examine student constructs more deeply (Fung 2002) and to explore questions such as how the stereotype emerges, how rapidly it forms, how it is reinforced, etc (Finson 2002) were slow in coming.

Mead and Métraux (1957) identified a firm link between images of scientist developed in school and through media exposure and the image of scientist uncovered in their research: "Straight across the country there is a reflection of the mass media image of the scientist, which shares with the school materials the responsibility for the present image" (p 388). As their research did not specifically question students about how they had developed their images, the link was at best hypothetical.

Despite the fact that school and the media have been the most frequently named potential sources for the stereotype of the scientist (Finson 2002; Schibeci 1986), it is only in the last few years that researchers have demonstrated causal links between the images or perceptions that students have of scientists and any source. Steinke et al (2007) used DAST to assess media influences on middle school students' perceptions of women in science. In interrogating students regarding their images, the researchers exposed connections between student depictions and images of scientists the young people had seen on television or in the movies. Given this connection, Steinke et al (2007) hypothesized that a media literacy intervention focused on critical assessment of media images of scientist would lead students who experienced the intervention to draw less stereotypical images of scientists than those that did not. Contrary to the hypothesis, the interventions had little impact on the images the students produced.

So What Works?

So what *does* change students' images of scientist? In what ways might young people come to know who scientists are beyond the stereotypes so often depicted on television and in the movies? Despite disproving their own hypothesis, Steinke et al (2007) did provide some indication that students with personal experience of scientists hold less gender-stereotyped images of scientists. Other research supports the idea that first-hand experience with science and scientists counters the stereotypical image and provides a more nuanced, complex understanding of scientist as human and science as human endeavour (Painter et al 2006).

In my own work with students, and particularly with indigenous students and their teachers, this type of hands-on intervention and involvement with scientist and engineer role models was central to how we developed programming. Anecdotally, I would say it was quite successful in encouraging students to change their perceptions of who scientists are and what they do. In an attempt to move beyond anecdotal evidence, Painter et al (2006) used pre- and post-interviews, along with field notes, student stories and a follow-up interview a year later, to demonstrate that involvement in a scientist-in-the-classroom project significantly shifted student perceptions away from the established stereotype of scientist, expanded student understanding of the scope of scientific work and helped students see scientists as complex, real people with real lives. More important, the study showed that the project had lasting impact, with shifts in student understanding that were "lucid and consistent" (p 188) even a year later. France and Bay (2010) have also shown that interactions with more authentic science and scientists—during a visit by senior high school students to a research institute—can be supportive in transforming how young people understand science, scientists and their own potential to become scientists.

So interaction with working scientists as role models seems to challenge the persistent stereotype identified by Mead and Métraux (1957), and may help young people see themselves as scientists. But, as Schibeci (1986) notes, there is very little space in the lives of young people for a realistic interface with scientists. My own experience suggests that while a good number of practising scientists and engineers are quite willing to commit time to interacting and working with young people, there are not enough scientists to go around. And so we are faced with expanding the means by which young people (and adults) are supported in coming to know who scientists are.

Some Practical Suggestions

That being said, there are a number of programs in Alberta that place scientists in schools or place high school students in research facilities. These programs include Scientists in Schools (www.scientistsinschool.ca/sis-sab.php), the Alberta Science Literacy Association (www.asla.ca/index.html) and university-based outreach programs such as the one available through the University of Alberta (www.outreach.ualberta.ca). Teachers might want to consider these programs as the first option in finding ways to open up broader understandings of science and scientists for their students.

Research from programs such as those listed suggests some basic steps that educators and scientists can take to make them more successful for all the parties and institutions involved. Key is collaboration between the classroom teacher and scientist (Howitt, Lewis and Waugh 2009) that begins prior to class visit(s) and extends for at least the time of the interaction. Teachers and scientists should be clear about their own expectations of the experience (eg, in terms of meeting curricular outcomes), safety issues, and what materials, audio video, additional supervision, etc. will be required or provided (Brooks, Dolan and Tax 2011). With good collaboration and open communication, student–scientist encounters can move beyond generic presentations to more focused explorations that allow students to consider questions and inquiries that have arisen as a component of their classroom work (Rumula et al 2011). It is in this type of interaction that personal relationships and connections can occur, not only extending students' understanding of who scientists are but allowing them to consider their own interest in pursuing science as a career (Buck et al 2008; Farland-Smith 2009).

Another manner in which students can be invited to explore who scientists are is through media portrayals. However, if, as it appears, young people are deriving stereotypical images and understandings of scientists from television and movies (Bovina and Dragul'skaia 2008; Steinke et al 2007), there is a need to integrate media in the classroom that gives more realistic, complex portrayals of science and scientists. Scientists talking about their research in their own words are often quite accessible. On shows like CBC's *Quirks and Quarks* (available as a podcast), hosts often ask questions that open up discussion of the motivations and inspirations for research, which can broaden understanding of what makes scientists who they are. Another good resource is iTunes U, with programs like *Science on Saturday* from the University of California. Some websites, such the Canadian National Research Council, provide text-based interviews with scientists that examine not only research but the balancing of work and family life. A more interactive site presenting the same type of exploration is A Day in the Life of an Engineer (http://nativeaccess.com/allabout/day_eng.html). And, of course, there are blogs. Blogs have a bit of a bad reputation, but, like any other source of information, they have to be weighed for their credibility. A good source of scientists writing about their own research, their research process, their life as scientists or research in general is *Scientific American* blogs (http://blogs.scientificamerican.com). Blogs connected to reputable magazines like *Discover* (http://blogs.discovermagazine.com) also tend to be readable and informative. Given the need for publicly funded research to be disseminated to the public, digital media resources such as the ones listed are a growing resource. Little research exists regarding their use in K–12 schools, so teachers considering how they support (or not) students' understandings of science and scientists might be well placed to make research contributions of their own.

Finally, students can be invited to explore who scientists are through books, both fiction and nonfiction. Carl Zimmer (2011) has a good list of high-school-accessible nonfiction books about science and scientists on one of his blog posts (http://blogs.discovermagazine.com/loom/2011/03/28/great-science-books-for-high-school-students-the-hive-mind-speaks). There are also novels such as Sagan's *Contact* (1985) or David Brin's *Earth* (1990). The use of novels in high school science always raises the question of time available, and yet there is a strong nature-of-science strand that runs through the Alberta high school programs of study for science. Certainly Science 10 (Alberta Education 2005a) would be an interesting place for such exploration. As students move from junior high into a more formalized experience of science, Science 10 has a strong emphasis on nature of science, a topic that includes the people who study science. It is neatly paralleled by Social Studies 10 (Alberta Education 2005b), in which students develop skills in examining multiple perspectives; synthesizing information; evaluating the logic underlying a position; making inferences and drawing conclusions; collaboration and consensus building; and assessing authority, reliability and validity of information (or evidence). In social studies, the skills are applied to economic, cultural and political interests on a global scale, but are analogous to the skill set desired in Science 10 (Alberta Education 2005a). Conversations and cooperation between teachers in these two subject areas may allow space to open up for the more extended exploration that literature would require.

Conclusion

I started with Ellie, and I will end with her, too. I do not think that every child should become a scientist, or even enjoy science; life would be way too boring if they all did. Nor do I believe that the primary impetus for science education should be international competitiveness or economic development—these are the results of good science education, not reasons for it. I do think that the job of educators is to support young people in becoming complete human beings, to show them the possibilities and the ways in which they can pursue those possibilities if they choose to do so. You cannot become something if you do not know that the possibility of it exists. And I suspect that you will not become something if you carry a negative stereotype about it around with you. So part of our jobs as educators is to support young people in understanding the complexity and limits of being a doctor, a nurse, a poet, a scientist. This is one of the things I love about Ellie—she embodies the complexities and limits of being fully human. When she first travels to space on a visit to a private space station, she finds herself standing in front of a huge window staring back at the Earth.

> There were many people she knew, even people who considered themselves religious, for whom the feeling of awe was an embarrassment. But you would have to be made of wood, she thought, to stand before this window and not feel it. They should be sending up young poets and composers, artists, filmmakers, and deeply religious people not wholly in thrall to the sectarian bureaucracies. This experience could easily be conveyed, she thought, to the average person on Earth. What a pity it had not yet been attempted seriously. (Sagan 1985, 283).

References

Alberta Advanced Education and Technology. 2008a. *Alberta's Action Plan*. Edmonton, Alberta: Alberta Advanced Education and Technology.

———. 2008b. *Building an Integrated Knowledge Economy: An Updated Information and Communications Technology Strategy for Alberta*. Edmonton, Alta: Alberta Advanced Education and Technology.

Alberta Education. 2005a. *Science 10*. Edmonton, Alta: Alberta Education. Available at http://education.alberta.ca/media/654833/science10.pdf (accessed November 24, 2011).

Alberta Education. (2005b). *Social Studies 10*. Edmonton, Alta: Alberta Education. Available at http://education.alberta.ca/media/773705/soc10_2.pdf (accessed November 24, 2011).

Bovina, I B, and L I Dragul'skaia. 2008. "College Students' Representations of Science and the Scientist." *Russian Education and Society* 50, no 1: 44–64.

Brin, D. 1990. *Earth*. New York: Bantam Books.

Brooks, E, E Dolan, and F Tax. 2011. "Partnership for Research and Education in Plants (PREP): Involving High School Students in Authentic Research in Collaboration with Scientists." *American Biology Teacher* 73, no 3: 137–42.

Buck, G A, V L Plano Clark, D Leslie-Pelecky, Y Lu and P Cerda-Lizarraga. 2008. "Examining the Cognitive Processes Used by Adolescent Girls and Women Scientists in Identifying Science Role Models: A Feminist Approach." *Science Education* 92, no 4: 688–707.

Buldu, M. 2006. "Young Children's Perceptions of Scientists: A Preliminary Study." *Educational Research* 48, no 1, 121–132.

Chambers, D W. 1983. "Stereotypic Images of the Scientist: The Draw-A-Scientist-Test." *Science Education* 67, no 2: 255–65.

Farland-Smith, D. 2009. "Exploring Middle-School Girls' Science Identities: Examining Attitudes and Perceptions of Scientists when Working 'Side-by-Side' with Scientists." *School Science and Mathematics* 109, no 7: 415–27.

Finson, K D. 2002. "Drawing a Scientist: What We Do and Do Not Know After Fifty Years of Drawings." *School Science and Mathematics* 102, no 7: 335–45.

France, B, and J L Bay. 2010. "Questions Students Ask: Bridging the Gap Between Scientists and Students in a Research Institute Classroom." *International Journal of Science Education* 32, no 2: 173–94.

Fung, Y Y H. 2002. "A Comparative Study of Primary and Secondary School Students' Images of Scientists." *Research in Science and Technological Education* 20, no 2: 199–213.

Howitt, C, S Lewis and S Waugh. 2009. "Analysis of an Exemplary Scientists in Schools Project in Forensic Science: Collaboration, Communication and Enthusiasm." *Teaching Science* 55, no 3: 46–51.

Krajkovich, J G, and J K Smith. 1982. "The Development of the Image of Science and Scientist Scale." *Journal of Research in Science Teaching* 19, no 1: 39–44.

Lemke, J L. 1993. "The Missing Context in Science Education: Science." Paper presented at the American Educational Research Association conference, Atlanta, Ga, nd. Available at http://academic.brooklyn.cuny.edu/education/jlemke/papers/gap-sci.htm (accessed November 24, 2011).

Mead, M, and R Métraux. 1957. "Image of the Scientist Among High School Students: A Pilot Study." *Science* 126: 384–90.

Merton, R K. 1973. "The Normative Structure of Science." In *The Sociology of Science*, 267–78. Chicago, Ill: University of Chicago Press.

Monhardt, R M. 2003. "The Image of the Scientist Through the Eyes of Navajo Children." *Journal of American Indian Education* 42, no 3: 25–39.

Painter, J, M G Jones, T R Tretter and D Kubasko. 2006. "Pulling Back the Curtain: Uncovering and Changing Students' Perceptions of Scientists." *School Science and Mathematics* 106, no 4: 181–90.

Polanyi, M. 1964. *Science, Faith and Society*. Chicago, Ill: University of Chicago Press. Orig pub 1946.

Ramsay, K, M Logan and K Skamp. 2005. "Primary Students' Perceptions of Science And Scientists: Affecting Senior Secondary Science Enrolments?" *Teaching Science* 51, no 4: 20–25.

Roe, A. 1961. "The Psychology of the Scientist." *Science* 134: 456–59.

Rumala, B B, J Hidary, L Ewool, C Emdin and T Scovell. 2011. "Tailoring Science Outreach Through E-Matching Using a Community-Based Participatory Approach." *PLoS Biology* 9, no 3: 1–5.

Sagan, C. 1985. *Contact*. New York: Simon & Schuster.

Schibeci, R. 1986. "Images of Science and Scientists and Science Education." *Science Education* 70, no 2: 139–49.

———. 2006. "Student Images Of Scientists: What Are They? Do They Matter?" *Teaching Science* 52, no 2: 12–16.

Song, J, and K-S Kim. 1999. "How Korean Students See Scientists: The Images of the Scientist." *International Journal of Science Education* 21, no 9: 957–77.

Steinke, J, M K Lapinski, N Crocker, A Zietsman-Thomas, Y Williams, S H Evergreen and S Kuchibhotla. 2007. "Assessing Media Influences in Middle School-Aged Children's Perceptions of Women in Science Using the Draw-A-Scientist Test." *Science Communication* 29, no 1: 35–64.

Sumrall, W J. 1995. "Reasons for the Perceived Images of Scientist by Race and Gender of Students in Grades 1–7." *School Science and Mathematics* 95, no 2: 83–90.

Zimmer, C. 2011. "Great Science Books for High School Students: The Hive-Mind Speaks." Available at http://blogs.discovermagazine.com/loom/2011/03/28/great-science-books-for-high-school-students-the-hive-mind-speaks (accessed November 24, 2011).

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Millsap and the Psychosexual Equivalent of Heat

Wytze Brouwer

It was a Wednesday afternoon in early fall. The weather had remained quite warm and we could actually sit on the patio at our university's faculty club. I was having a drink with two colleagues—Jenny Platt, my favorite biology colleague, and Brian Adams, our resident astronomer. Bert Millsap, my tubby psychology colleague, had been away at a conference for more than a week, but I expected him to join us some afternoon this week. And just in case the reader might get the impression that university professors spend every afternoon at the faculty club, I have to emphasize that I had chosen part-time retirement when I reached the magical age at which such choices were possible.

Millsap, despite the dean's efforts, refuses to retire and swears that he will continue teaching and doing research until they have to carry him out. In fact, I was just responding to a question from Brian as to what type of research Millsap was actually involved in. We all reflected on some of the spectacular research projects Millsap had become world-famous for, such as his sleep-deprivation research, for which he gave an invited address at a major international congress sporting a black eye caused by a research subject who objected to being kept awake too long.

"In fact, speak of the devil—here he comes. We can ask him himself."

Millsap arrived, waved his right arm at the bartender, and waited for his Rosemary Sunrise (recipe available on request). Millsap never speaks until he has had a deep quaff of his drink and settles back to join any debate that might be ongoing.

"Welcome back, Bert." I'm probably the only one on campus that regularly uses Millsap's first name. "How was Heidelberg?" It's interesting to note that psychologists don't hold conferences in Pittsburgh, or Winnipeg, but choose rather more exotic places. Hawaii is a favoured destination for psychologists, too, especially in January.

”We had a great conference, Jenny. I was elected a fellow of the Bavarian Academy of Science and it was quite a celebration."

"Where did they hold the celebration? In the castle?"

"Most of the meetings were held at the University of Heidelberg, which is in the centre of town, but for the main dinner and celebration, we were brought to Schloss Heidelberg by a little train that saved us the 300-metre uphill walk to the castle. The highlight of the dinner was the wine, served from the famous old barrel that used to hold the wine collected from the taxpayers."

"Was this before your speech or after?"

"Both before and after. The little acceptance speech was nothing to worry about. I had given my invited speech a day earlier, so I could really relax and enjoy the wine."

"You know," ventured Brian Adams, "I've never liked German red wines very much. I prefer the French Beaujolais." We followed this trend in the discussion for a while, comparing the merits of Argentinian Malbec, Australian Shiraz and the Beaujolais before finally agreeing that taste was probably a very personal thing. Probably, I say, although each of us clearly indicated that, even given the personal nature of taste, everyone else's taste buds were of course inferior to our own. The only memorable part of the discussion (or argument) as the discussion wore on was Millsap's introduction of the topic of *kumis*, a Siberian wine made from fermented mare's milk. Apparently he had once drunk this on a visit to Irkutsk, and since none of us had ever tasted kumis, we could hardly disagree with his claim that it was one of the finest drinks in the world.

"And it promotes urination even more than beer," was his summary statement.

"You're disgusting, Millsap. What on earth has that to do with our discussion, anyhow? You're always bringing up irrelevancies in our discussions." Jenny Platt is often critical of Millsap's mental zigzags.

"It wasn't irrelevant to me," replied Millsap, "I was up practically the whole night."

I decided it was time to end this discussion because I was interested in hearing a bit more about Millsap's invited talk in Heidelberg. Millsap's wife, Helen, had told me that he had been involved in research that had kept him outside many nights during the past, fairly cold winter, but Bert himself had been quite secretive about his doings. He wanted to wait until his research was ready to publish.

"So what did you actually talk about in Heidelberg?"

"Well, the title of my talk was 'The Psychosexual Equivalent of Heat.' I spent most of last winter researching this topic. I had a grant from the Social Sciences Research Council to hire some undergraduate students to serve as my research subjects and took them out into the river valley to do the study."

"Hmmm, what exactly did you do with these students?" As usual, we were all quite interested in Millsap's research, since the topics were invariably unusual.

"I had the students build a number of fairly large quinzees so that each quinzee could hold up to twelve students for a couple of hours. We measured the initial temperature inside each quinzee …"

"Just a minute, Millsap, what exactly is a quinzee? I thought it was a Japanese computer game of some sort."

"You're just an ignoramus, Brian; you're talking about a *quintzee*. A quinzee is a snow hut. You build one by piling up a lot of snow on one spot and leaving it an hour so that the snow begins to bind together, and then you hollow it out. You put a tarp on the bottom and people can sit inside."

"Inside and freeze, I suppose?"

"No, that's the interesting part. It takes only a short time before body heat raises the temperature inside a quinzee so that it becomes very comfortable inside. Some of the groups started playing poker inside their quinzee."

"So what was the point of the exercise?"

"I wanted to quantify the body heat produced by different groups of students under differing conditions. For example, for the first part of the experiment, I placed eight male students in a number of quinzees, and eight female students in other quinzees. I asked them to read their psychology textbooks, and after one hour we measured the final temperature in each of the quinzees."

"So what did you find?"

"Well, the average temperature in the boys' quinzees rose from –11.2°C to +13.4°C in one hour, but the temperature in the girls' quinzees rose to only 11.9°C. If you convert that to energy output per second, the average male subject produced the energy equivalent of a 63.4-watt light bulb, whereas the average female subject produced only 57.8 watts."

"I suppose you corrected for body weight, Millsap?"

"Yeah, yeah, yeah, Brouwer, I did, but the boys still produced significantly more energy than the girls. But I wanted to do the experiment under different conditions. So I took the students back to university and introduced them to the card game Hearts, which most of them were familiar with. After a few sessions of practice we went back to the quinzees and repeated the measurements while both groups of students played Hearts."

"So what difference would that make?" asked Jenny. "In fact, I would predict that the temperature might rise a little bit because of the element of competition introduced."

"Not a bad guess, Jenny, but not good enough. The temperature in the boys' quinzees increased another 1.8°C, which meant they were producing energy at a rate of 67.4 watts, while the average temperature in the girls' quinzees rose only 0.15°C, which meant they increased their energy output to about 58.1 watts!"

"You mean you measured the differences in the competitiveness of the two sexes …"

"Yeah, not bad, eh? Only I didn't expect the results to be that significant."

"So, was that it, Millsap?"

"No, no, I then decided to study the temperature differences when I put mixed groups of students in the quinzees. And to my surprise, when you put four boys and four girls into a quinzee for one hour, the average temperature rose to about 14.6°C.This shows that there is obviously a greater heat output due to some sort of sexual tension. There was only one puzzling result. In one of the mixed tents, the final temperature rose to over 20°Celsius—20.2°C, in fact. I need to investigate the conditions inside that quinzee a little closer before I can hypothesize why that temperature rose so much higher than any other."

We started laughing. All of us were obviously thinking the same thing. And when I say "all of us," I include all the bystanders who had gathered around while Millsap was describing his experiment at the top of his voice.

He looked irritable. "What are you guys laughing at? This is obviously an outcome that needs further investigation. You guys are as bad as the guy in the audience in Heidelberg who got up and interrupted me: 'Herr Professor Millsap. Diese Studenten haben vielleicht *Hanky-Panky* gespielt.' The guy almost ruined my speech because people kept laughing and pointing at me during the rest of the speech and yelling 'hanky-panky.' The expression seemed to humour a simple-minded German audience. The next day I was on German national television, so I suppose it was a success after all. They all encouraged me to continue my research and update them at the next annual conference. However, the next conference is in Nigeria, and quinzees won't mean much to them."

Diversity • Equity • Human Rights Diversity • Equity • Human Rights

Specialist councils' role in promoting diversity, equity and human rights

Alberta's rapidly changing demographics are creating an exciting cultural diversity that is reflected in the province's urban and rural classrooms. The new landscape of the school provides an ideal context in which to teach students that strength lies in diversity. The challenge that teachers face is to capitalize on the energy of today's intercultural classroom mix to lay the groundwork for all students to succeed. To support teachers in their critical roles as leaders in inclusive education, in 2000 the Alberta Teachers' Association established the Diversity, Equity and Human Rights Committee (DEHRC).

DEHRC aims to assist educators in their legal, professional and ethical responsibilities to protect all students and to maintain safe, caring and inclusive learning environments. Topics of focus for DEHRC include intercultural education, inclusive learning communities, gender equity, UNESCO Associated Schools Project Network, sexual orientation and gender variance.

Here are some activities the DEHR committee undertakes:

- Studying, advising and making recommendations on policies that reflect respect for diversity, equity and human rights
- Offering annual Inclusive Learning Communities Grants (up to $2,000) to support activities that support inclusion
- Producing *Just in Time*, an electronic newsletter that can be found at www.teachers.ab.ca; Teaching in Alberta; Diversity, Equity and Human Rights.
- Providing and creating print and web-based teacher resources
- Creating a list of presenters on DEHR topics
- Supporting the Association instructor workshops on diversity

Specialist councils are uniquely situated to learn about diversity issues directly from teachers in the field who see how diversity issues play out in subject areas. Specialist council members are encouraged to share the challenges they may be facing in terms of diversity in their own classrooms and to incorporate these discussions into specialist council activities, publications and conferences.

Diversity, equity and human rights affect the work of all members. What are you doing to make a difference?

Further information about the work of the DEHR committee can be found on the Association's website at www.teachers.ab.ca under Teaching in Alberta, Diversity, Equity and Human Rights.

Alternatively, contact Andrea Berg, executive staff officer, Professional Development, at andrea.berg@ata.ab.ca for more information.

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