Appropriately Diverse?
The Ontario Science and Technology Curriculum Tested Against the Banks Model

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Abstract

The growing diversity of Ontario's population is increasing pressure on the education system to ensure that all students receive equal opportunities to excel academically and develop personally. Students are more likely to succeed if their own racial, ethnic, and cultural identity is reflected in the classroom. This observation applies no less to science than it does to the humanities and social sciences. While science has a universal quality, flowing from its ability to transcend geographic and cultural frontiers, it is also diverse in origin. Science is a global story of achievement in which nearly every racial, ethnic, and cultural group has played a vital role. This diversity is not adequately appreciated in Ontario, Canada, or the Western world because the default assumption of most Europeans and European descendants is that science is fundamentally Western. Science curricula must therefore direct, convince and equip teachers to rebut this assumption and thereby engage the interest of students of all backgrounds. This paper uses classical

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content analysis to test the 1998 and 2007 versions of the Ontario science curriculum for Grades 1 to 8 against James Banks's four approaches for ensuring racial, ethnic and cultural diversity in school programs. Our findings show that neither the 1998 nor the 2007 curricula, despite the latter's claim to implement the principles of an anti-discriminatory education, challenge the perception of science as fundamentally Western in origin.

Keywords: Multiculturalism, science education, anti-discrimination, history of science

Précis

La diversité croissante de la population ontarienne presse de plus en plus le système d'éducation afin qu'il fasse en sorte que tous les étudiants aient les mêmes chances d'exceller au point de vue pédagogique et de se développer au plan personnel. Les étudiants sont plus susceptibles de réussir si leur identité raciale, ethnique et culturelle se reflète dans la salle de classe. Cette observation s'applique tout autant à la science qu'elle ne s'applique aux sciences humaines et sociales. Bien que la science ait une qualité universelle, découlant de sa capacité à transcender les frontières géographiques et culturelles, elle est aussi issue d'origines diverses. La science représente une vaste histoire de réalisations au cours de laquelle presque tous les groupes raciaux, ethniques et culturels ont joué un rôle essentiel. Cette diversité n'est pas suffisamment appréciée en Ontario (Canada), ou en Occident, car l'idée préconçue de la plupart des Européens et de leurs descendants veut que la science soit fondamentalement occidentale. Les programmes d'enseignement des sciences doivent donc orienter, convaincre et équiper les enseignants pour qu'ils puissent réfuter cette hypothèse et ainsi susciter l'intérêt des étudiants de tout horizon. Cet article utilise l'analyze de contenu classique pour tester les programmes d'enseignement des sciences de l'Ontario de 1998 et de 2007, à l'intention des élèves de la première à la huitième année, en fonction des quatre approches de James Banks pour assurer la diversité raciale, ethnique et culturelle dans les programmes scolaires. Nos résultats révèlent que ni les programmes de 1998 ni ceux de 2007, malgré la prétention que ce dernier met en œuvre les principes d'une éducation antidiscriminatoire, ne remettent en question la perception que la science est fondamentalement d'origine occidentale.

Introduction

Ontario is already one of the most racially, ethnically, and culturally diverse jurisdictions in Canada, if not in North America. Steady streams of newcomers from every corner of the planet are adding unprecedented richness to Ontario society. This is amply confirmed by reference to a few key statistics. Ontario is currently the destination for more than 50% of all immigrants to Canada, the majority of whom settle in the Greater Toronto Area. The province is home to almost three million persons who self-identify as members of visible-minority groups, a figure that represents more than 50% of Canada's overall visible-minority population. Furthermore, Ontario's visible-minority population is expanding more than four times faster than the population as a whole (*Ontario's Equity and Inclusive Education Strategy,* 2009).

While this growing diversity offers tremendous opportunities for social and personal development, it also presents some important challenges. These challenges must be confronted if Ontario is to realize its potential to become a model of fairness and equality that truly fulfills the promise of the Canadian Charter of Rights and Freedoms. More specifically, the province's education system must find ways to better engage its visible-minority and Aboriginal student populations to ensure that these students enjoy the same opportunities for personal and career success as their peers. In this regard, the teaching of science is of particular importance. Indeed, the pervasive and indispensable role played by science and technology in all facets of 21st-century life mandates that all pupils receive equal opportunities to become fluent in core scientific principles and their application (Corrigan, Dillon, & Gunstone, 2007).

Science from Grades 1 to 8 plays a formative role in shaping students' course selections in high school and, ultimately, their post-secondary and career choices. Grades 1 to 8 are valuable opportunities for schools to reach all students with the message that science is not only incredibly valuable from a practical standpoint but also fascinating in its relationship to students' daily lived experiences. One of the most fascinating aspects of science is its diverse origins—a fact that is frequently overlooked by educators and the public as a whole. The default perception of many people in Western countries, including Canada, is that science is a fundamentally Western endeavour (Hodson, 1992a, 1992b; Krugly-Smolska, 1996). Yet science is a truly global story, one to which virtually every race, ethnicity, and culture has made vital contributions. One of the primary contentions of this study is that, if students are exposed to the diverse roots of science, there will be a tangible improvement in visible-minority students' level of interest in pursuing science education and careers (Atwater, 1993; Bisbee, 1996).

The primary purpose of this paper is to assess the *The Ontario Curriculum, Grades 1–8: Science and Technology 2007*, also known as the *Ontario Science and Technology Curriculum* (OSTC; Ontario Ministry of Education, 2007), specifically in terms of the extent to which it promotes principles of multicultural education by exposing students to the diverse origins of science. This assessment includes a comparison of OSTC 2007 with its immediate predecessor from 1998 (Ontario Ministry of Education, 1998). The secondary purpose of this paper is to establish the main reasons why Ontario students should be exposed to the diverse origins of science. This discussion includes the presentation of arguments and evidence supporting our view that every race, ethnic group, and culture has made crucial contributions to science and that the Ontario science curriculum must combat the default opinion of many people that science is a fundamentally Western enterprise (Hodson, 2009; Matthews, 1994).

The Unity and Diversity of Science

A brief examination of science as it is practised around the world would suggest that there exists a broad consensus that core scientific principles and techniques emanate from the West. This is a misconception that has its roots in the default perception of many Europeans and descendants of Europeans that anything powerful, great, and global must surely be a product of "Western civilization" (Hodson, 1993, 2009). Edward Said considered this misconception as manifestation of "Orientalism"—a concept he propounded in his landmark book of the same name (1978). Said perspicaciously identified and expounded upon a long-established tendency by Westerners to appropriate the achievements of the rest of the world—namely those of "the East"—while at the same time constructing highly misleading caricatures of other peoples, cultures, and religions. Indeed, the Orientalists' claim to ownership of knowledge presumes to impose a descriptive vision upon the "other"—a vision that seeks to enhance the privilege of the "civilized" European powers over the "primitive," less-developed peoples of the world. In Said's view, Orientalism continues the discourses of power articulated by the European imperial powers since the 19th and early 20th centuries. Unfortunately, this concept and its study continued to be decided by many in the West:

> The literary-cultural establishment as a whole has declared the serious study of imperialism and culture off-limits. For Orientalism brings one up directly against that question—that is, to realizing that political imperialism governs an entire field of study, imagination, and scholarly institutions. (Said, 1978, pp. 13–14)

While it is undeniable that Western political and economic imperialism to some extent contributed to the worldwide dissemination of science as we know it today, it is patently false to assume that Europeans "invented" science or that they can be credited with all or most scientific achievements. The seeming scientific leadership of Europe—and of the countries that were largely populated by Europeans—is a relatively recent phenomenon, one that arguably began in the 16th and 17th centuries with the "Scientific Revolution" and that reached its apogee with the Industrial Revolution and the economic growth that followed. As explained by Margaret Jacob, "the mechanization of nature through the discoveries of the new science provided early industrialists with the arsenal of new knowledge, as well as with new metaphors of self-justification, which could be applied in the service of their economic interests" (1988, p. 271).

A long-term examination of the historical record would reveal that the West built its now fading technological, industrial, and military dominance on scientific traditions that stretch back for millennia and that are no less diverse than the Canadian mosaic itself. Science is truly a global story of achievement to which virtually every race, ethnicity, and culture has made and continues to make an indispensable contribution (Hill, 1993; Hodson, 1998; Huff, 1993; Krugly-Smolska, 1996).

Many scientific discoveries and technological innovations are the products of long lines of historical development that weave their way through multiple cultures and geographic regions. These discoveries and innovations are not any more "European" or "Western" than they are East Asian, Arab, African, or otherwise. For instance, around 150 BCE, the Greeks used mathematical projections to develop the original astrolabe. Then, in the eighth century CE, Muslim astronomers perfected the astrolabe in order to determine prayer times and the direction of Mecca. This instrument then reached the Spanish region of Andalusia in the 11th century through Christian missionaries and, in turn, played an indispensable role in European expansion overseas (Lindberg, 2008; Masood; 2009;

Montgomery, 2000). Another revealing example is provided by the remarkable achievement and legacy of *The Canon of Medicine* (as cited in Masood, 2009, p. 105). This multi-volume work, compiled around 1025 CE by the Persian polymath Ibn Sina (known as Avicenna in the West), is a detailed survey of over 1,500 years of medical knowledge developed by the Persians, Greeks, Romans, Arabs, and many other peoples. *The Canon of Medicine* was a product of the Islamic Golden Age, a period during which Muslim scholars directed much of their attention to study of Persian, Greek, Roman, and Indian texts. This masterpiece commanded unmatched respect by, for example, serving for six centuries as one of the standard medical textbooks in Europe; its authority is confirmed by the fact that 60 editions were published between 1500 and 1647 (Masood, 2009, p. 104). As these examples richly illustrate, it is the blending of multiple streams of scientific knowledge that has made science what it is today.

It can be argued that the recent scientific dominance of the West is largely based on the borrowing, adaptation, and application of discoveries made elsewhere. As Montgomery demonstrates through multiple historical examples, it is "the *power of translation* that has commanded in the building of what we call today Western science" (2000, p. 1; emphasis added). In 2004, Eva Krugly-Smolska provided a particularly insightful overview of the globalization of science:

> The complex relationship between science at the national and international levels suggests that the term "transnational science" might be an appropriate one. It acknowledges science done at the national level but implies that any such work has cross-border implications. It also emphasizes the cross-border flow of ideas, information, protocols and practices, as well as people. It has the added benefit of reminding us of transnational corporations in this era of economic globalization . . . Different countries may still tackle different questions and use different approaches, but the knowledge produced becomes (eventually—patents notwithstanding) part of the transnational flow. (2004, p. 3)

Rationale for Exposing Students to the History of Science

As discussed above, while science might be transnational in its contemporary character, it is also multinational and multicultural in its origins. There are several important reasons why Ontarian students should be exposed to the rich and varied roots of scientific knowledge. The first relates to scientific accuracy itself. It would be academically dishonest to leave students with the impression that science is fundamentally European when, in reality, it is no more European than it is, for instance, Chinese, Arab, or African. There can be no argument with the proposition that the education system has a responsibility to disseminate the truth.

The second reason for exposing students to the diverse origins of science is closely related to the increasingly multiracial, multiethnic and multicultural character of Canada in general and of Ontario in particular. A notable example of this trend is provided by Toronto's Driftwood Public School, where

> sixty percent of the school's 700 students speak a language other than English as a first language, and one in five have been in Canada less than five years; 30 language groups are represented among the students and families. (Dunning, 1999, p. 1)

In Canada, there will be more minority students in schools in future, as indicated by a recent study by Samuel and Basavarajappa (2006, p. 247):

> The 2005 projections suggest that visible minority population will almost double by 2017 as compared with increases of 1 to 7% for the rest of the Canadian population. The numbers of visible minority persons may range from 6.3 to 8.5 million in 2017, accounting for roughly one Canadian in five. As in 2001, Ontario and British Columbia would continue to have over-representation of the visible minority population in 2017. The two provinces may account for about 57% and 20% of the total visible minority population respectively (Statistics Canada, 2005).

Broader measures confirm the rapid expansion of the visible-minority population as a whole, and this phenomenon is inevitably resulting in an equivalent expansion of the visible-minority student population. As explained in *Ontario's Equity and Inclusive Education Strategy 2009*, drawing on the 2006 Census (Ontario Ministry of Education, 2009).

> Ontario continued to be the province of choice for more than half (52.3%) of the 1.1 million newcomers who arrived in Canada during the 2001–2006 period. More than half of these newcomers will settle in areas outside of Toronto . . . The 2006 Census enumerated an estimated 2.7 million Ontarians who identified themselves as members of the visible minority population, representing more than half of Canada's total visible minorities. Between 2001 and 2006, Ontario's visible minority population increased more than four times faster than the population as a whole (not counting those who self-identified as Aboriginal) . . . By 2017, about one-fifth of our population will be members of diverse faith communities including Islam, Hinduism, Buddhism, and Judaism, in addition to a growing number of individuals without a religious affiliation. (p. 8)

In Ontario and in other jurisdictions characterized by high and increasing levels of diversity, there is a commensurate need to foster respect and understanding among racial, ethnic, and cultural groups. To communicate either explicitly or implicitly that science is essentially Western would encourage some students to see themselves as members of the "superior" group and other students to see themselves as members of the "inferior" group. Conversely, disseminating the truth about the origins of science would help to combat attitudes of group superiority and inferiority as well as to promote understanding among students of all backgrounds. Greater respect—both reflexive and mutual—would be the result.

The third reason for exposing students to the diverse origins of science is to encourage students from marginalized racial, ethnic, and cultural groups to pursue science education and to seriously consider science or a related field for their career. Although some reviews indicate that "many Asian communities pursue science fields due to parental hopes and aspirations," empirical evidence from Ma's (2003) analysis of the Youth in Transition Survey (YITS)/ Programme for International Student Assessment (PISA) database shows that immigrant students had lower scores in reading and science, as measured by the standardized tests used in the YITS/(PISA), than did their non-immigrant peers" (as cited in Krahn & Taylor, 2005, p. 35). Therefore, as indicated by research, "non-immigrant students in Canada outperformed immigrant students in both reading and science achievement" (Ma, 2003, p. 20 as cited in Shipley, 2009). Exposure to the true origins of science would provide all students with the opportunity to see themselves reflected in and represented by school knowledge. This would, in turn, provide particular encouragement to visible-minority and Aboriginal students. Put another way, "More careful study of the history of science can ensure that these [non-Western] contributions are not forgotten and that appropriate role models are available to inspire the next generation" (Brush, 1989, p. 65). By using this approach to engage the interest of all students, but especially that of students of non-European origin, Ontario schools would make progress in reversing what many studies have already proven: that many students lack interest in the knowledge and skills privileged by the elite because the curriculum does not relate to or connect with their lives or identities (Giroux, 1981). These studies also confirm that members of minority and Aboriginal groups are among those most marginalized from the learning process, and that this marginalization in large measure results from a sense of alienation engendered by the curriculum itself (for a review see Bianchini, 1999).

Educators must be pro-active and systematic in engaging all students in the learning process by combating all elements of the education system that could foster a sense of alienation. Ensuring that science curricula expose students to the diversity embedded in scientific knowledge is an important step in fighting the feelings of alienation experienced by some visible-minority and Aboriginal youth. To presume that the engagement of these students can be achieved by purging the curriculum of all or virtually all mentions of the origins of science would be to ignore the default assumption of many people that science is a fundamentally European endeavour. In order actually to rebut this assumption, teachers must be *directed* to demonstrate that virtually all major racial, ethnic, and cultural groups around the world have made vital contributions to scientific knowledge. Not only must teachers be directed to do this, but they must also be *convinced* of the importance of non-European scientific achievements. And, just as importantly, they must be *equipped* with concrete examples to share with students. Only if the curriculum provides appropriate guidance to teachers will all students—visible-minority and non-visible-minority alike—reap the benefits of exposure to the diverse origins of science.

The benefits of exposing Ontario students to the multicultural history of science are closely related to many already documented benefits of infusing science education with historical perspectives regardless of the origin of those perspectives. There exists extensive academic literature on the importance of supplementing science education with historical background information. For instance, Leite (2002) emphasizes Hodson's holistic approach to teaching science (pp. 333–334):

> According to Hodson (1992), science education includes three major aspects: learning science, learning about science and doing science . . . Hodson (1992) defines learning about science as "gaining some understanding of the nature of science and scientific practice, and an appreciation of the complex relationship between science technology and society" (p. 65). In a recent paper the same author argues that ". . . 'getting a feel for scientific practice'. . . requires that we utilize a wide range of other learning experiences—among them the use of historical case studies" (Hodson, 1996, p. 226).

Thus, Hodson stresses the importance of learning about the relationship between science and society and acknowledges that this, in turn, requires the use of historical case studies.

The benefits of learning about the history of science even extend to the acquisition of scientific concepts. The historical dimension—especially with regard to paths of scientific development—illuminates the *process* of scientific inquiry and thus can help to turn students away from rote learning and toward more critical thinking. According to Brush (1989), "The essence of such an approach [the historical approach] is not merely to assert the conclusions but to show how they were reached and what alternatives were plausibly advocated" (p. 61). A noted example of adding historical and cultural content to science instruction was the "Project Physics Course." This high-school science curriculum was developed at Harvard University in the 1960s and, by the 1970s, was being taken by approximately 15% of students in the United States (Matthews, 1988). According to Matthews,

> These students learned not to think in terms of a standardized "scientific method" but gained an appreciation of the roles of diverse approaches, imagination, confirmation, and instrumentation in the pursuit of scientific knowledge (Aikenhead 1974). Further, their knowledge of the discipline did not suffer in virtue of this appreciation (Brush 1987, 78). (1988, p. 70)

Another often identified reason for exposing students to the historical background of science is the positive impact on students' attitudes to science and on their general world view. According to Brush (1989), "As Thomas L. Russell (1981) points out, the experience of the Project Physics Course shows that we *can* [emphasis in original] improve attitudes toward science and the understanding of how science works by the use of history" (p. 63).

It is noteworthy that some European—especially British—educators were writing about the virtues of a historical approach in the early twentieth century. At that time there was legitimate concern that science would be seen by students as dry and dehumanized, and that this would undermine their enthusiasm for the subject. Measures had to be taken to give science a human face. According to Leite,

> The history of science was seen then as a way of humanising the science that had been introduced into the curriculum a few years before but that was already suffering attack. In fact, science was criticised and even considered a "cold and dehumanised subject, not concerned with people" (Livingstone 1916, p. 30). Some students were even discouraged by teachers from pursuing science. (Leite, 2002, p. 335)

Moreover, the potential for historical knowledge to provide students with a more holistic understanding—and thereby to stimulate their interest—was emphasized by the British Association for the Advancement of Science, which

> in 1917 had urged the historical approach to science teaching, saying that the history of science was a "solvent that dissolved the artificial barriers between literary studies and science that the school timetable sets up" (BAAS 1917, 140). In the following year the J.J. Thompson Report endorsed these claims (Waring 1979). (Matthews, 1988, p. 69)

The above discussion confirms that the idea of infusing science instruction with historical perspectives has a long tradition and finds substantial support in the educational literature. The time has come to make this approach relevant to Ontario in the 21st century—to take advantage of the many benefits that have been documented over the last hundred years and to direct and tailor them toward the needs of an increasingly multiracial, multiethnic, and multicultural society.

Methodology: Assessment Criteria for Science Curricula

Before attempting to reform any curriculum, one must first assess its most recent version as well as any relevant previous versions. Such an assessment requires the application of targeted test criteria. Specifically, we are interested in assessing how and to what degree the OSTC exposes students to the diverse origins of science. In other words, our vision is that every student be represented in what he or she is learning.

One of the most respected models for ensuring that school programmes properly reflect racial, ethnic, and cultural diversity was developed by James Banks, director of the Center for Multicultural Education at the University of Washington (1989). Banks defined four general approaches for integrating racial, ethnic, and cultural diversity into school programmes. These are the "Contributions Approach," the "Additive Approach," the "Transformation Approach," and the "Social Action Approach." According to Banks, when the Contributions Approach is applied

> teachers *insert isolated facts* about ethnic and cultural group heroes and heroines into the curriculum *without changing the structure of their lesson plans and units* [emphases added]. Often when this approach is used, lessons about ethnic minorities are limited primarily to ethnic holidays and celebrations. (Banks, 1997, p. 13)

Banks's Additive Approach bears many similarities to the Contributions Approach—the main difference being that, whereas the latter is limited to the insertion of "isolated facts" into lessons, the former involves adding supplementary units that "integrate content about ethnic and cultural groups into the school curriculum." Indeed,

> in this approach, the organization and structure of the curriculum remains unchanged. Special units on ethnic and cultural groups are added to the curriculum, such as units on African Americans in the [American] West, Indian Removal, and the internment of Japanese Americans. (Banks, 1997, p. 14)

The Transformation Approach is very different from the first two approaches because it actually involves changing the structure and core contents of the curriculum rather than simply making ad hoc additions to lessons (the Contributions Approach) or supplementing the existing curriculum with special units (the Additive Approach). Thus,

> The Transformation Approach brings content about ethnic and cultural groups from the margin to the center of the curriculum. It helps students to understand how knowledge is constructed and how it reflects the experiences, values, and perspectives of its creators. *In this approach, the structure, assumptions, and perspectives of the curriculum are changed* so that the concepts, events, and issues taught are viewed from the perspectives and experiences of a range of racial, ethnic, and cultural groups. The *center of the curriculum* [emphases added] no longer focuses on mainstream and dominant groups, but on an event, issue, or concept that is viewed from many different perspectives and points of view. (Banks, 1997, p. 15)

Finally, the Social Action Approach promotes students taking positive action to effect social and democratic change at the micro and macro levels, especially with regard to improving understanding and respect among racial, ethnic, and cultural groups. Thus,

> An important goal of multicultural education is to help students acquire the knowledge and commitments needed to make reflective decisions and to take personal, social, and civic action to promote democracy and democratic living. Opportunities for action help students to develop a sense of personal and civic efficacy, faith in their ability to make changes in the institutions in which they live, and situations to apply the knowledge they have learned . . . Action activities and projects should be tuned to the cognitive and moral developmental levels of students. Practicality and feasibility should also be important considerations. (Banks, 1997a, p. 15)

Banks takes a holistic view of the challenges facing educators who aim to fight racism and other forms of prejudice. Indeed, educators must strive to

> help students to re-conceptualize multiculturalism so that they understand the complex, unstable and hegemonic nature of culture and how their educational and occupational opportunities are structured and affected by characteristics such as class, gender, ethnicity and race. Ultimately, the success of the students will be determined by the extent to which the school environment, the curriculum content and school practices reflect and acknowledge the diverse cultural backgrounds represented within their classes and society as a whole. (Banks, 2003, p. 226)

In the sections that follow, these four approaches are applied as test criteria to the 1998 and 2007 versions of *The Ontario Curriculum, Grades 1–8: Science and Technology*.

A Post-Colonial Perspective

A significant number of studies have emerged over the past three decades that consider school curricula from a post-colonial perspective (Apple, 1999; Giroux, 1983; McLaren, 1989; Willinsky, 1998). These studies have arisen as a result of the development of post-colonial theories by Bhabha (1994), Said (1978, 1993), and Spivak (1990, 1993). We employ post-colonial theory to critique the current approach of the OSTC. Our critique is one of an ideology that perpetuates Eurocentrism, colonialism, and the construction of the non-Western "other" (Gough, 1998, p. 187) in the curriculum. By "post-colonial" we refer to the theoretical lenses that we use to deconstruct the pattern of undue emphasis on European and quasi-European knowledge, ways of knowing, cultural production, and representation in education. We focus on how science has continued to be introduced and emphasized as a "Western enterprise." The post-colonial position we have taken is one "that calls for a major rethinking of given categories, histories, assumptions, and fixed structures (of science knowledge), and brings a greater sense of understanding to the interpretation of social and cultural production" (Pennycock, 1998, p. 49 as cited in London, 2006). We are taking a post-colonial perspective that "attempts to re-instate the marginalized in face of the dominant" (Gough, 1998, p. 194).

We concur with Giroux's longstanding argument that "post-colonialism challenges how imperial centres of power construct themselves through the discourses of master narratives and totalizing systems; they contest the monolithic authority wielded through presentations of brute institutional relations and of claims to universality" (1992, p. 20). This means that through post-colonial lenses we seek to analyze and challenge the currently existing structures of power and control as well as the power relationships that are embedded within the curriculum documents. Through these lenses we seek to demonstrate how the dominant group presents scientific inquiry as being inherently Western—as being detached from any previous culture of inquiry in history. As Apple points out, "the power of a dominant class to influence the production of certain kinds of technical knowledge is needed for both the accumulation of capital and the legitimization of exciting power arrangements of the given society" (as cited in Giroux, 1999, p. 28).

Classical Content Analysis of the Curriculum

Our study explores how the 1998 OSTC dealt with the diversity of the Ontario student population and the extent to which the 2007 OSTC, through its claim to implement the principles of an anti-discriminatory education, is in fact inclusive and anti-discriminatory. The underlying premise of this research is that a science curriculum should be relevant to students' lives and experiences. In our view, anti-discriminatory education should be inclusive of ethnicity (for instance, Anglo-Saxon, French, Aboriginal, African, East Asian, South Asian, and Middle Eastern Arab[1]), gender (male and female), social class (middle and underprivileged socio-economic class), and people with special needs.

These features were examined through a classical content analysis (CCA) of the two OSTC documents (1998 and 2007). CCA is seen as a text interpretation method in case study research (Kohlbacher, 2006). In this research CCA began with a thorough review of the entirety of both texts. CCA was chosen in order to gain a sense of the scope of anti-discrimination messages, representations of diversity and any non-Western knowledge within the 1998 and 2007 versions of the OSTC. Yet its limitations are the same as for a qualitative study: the results are not generalizable and are not transferable to other curriculum documents. Other studies such as Craig (1992) used CCA to analyze and compare differences between three day parts; the sample was chosen from three time periods: daytime, evening prime time, and weekend afternoon sportscasts. CCA begins by "applying a set of codes for a set of qualitative data . . . validity itself depends on the collective opinion of researchers" (Ryan & Bernard, 2000, p. 785). The two researchers (one is an assistant professor of curriculum and pedagogy, and the other is an associate professor of science education) coded the areas where race, gender, socio-economic class, disability, and culture were mentioned in the curriculum document. They were then assigned as multiple coders; verifying the interpretations each one came up with, they also performed a systematic analysis of the texts' contents. According to David Silverman, content analysis is performed simply when "the researchers establish a set of categories and then count the number of instances that fall into each category" (2000, p. 826). The crucial requirement, he argues, is that the categories be sufficiently precise to enable different coders to

1 According to the *Canada Year Book 2012*, "Canada's largest group of recent immigrants were from Asia (including the Middle East), accounting for 58% of immigrants in 2006, Europe, in second place, accounted for 16%" (p. 160).

arrive at the same results when the same body of material is examined, which is the case as will appear in the following discussions.

The content analysis was then complemented with a thematic analysis. This involved searching the texts for themes such as gender, ethnicity, aboriginality, disability, and social class. After the initial thematic analysis, different streams of data were assessed to identify recurring topics and themes associated with race, gender, culture, disabilities, and special needs (Winter & McClelland, 1978). For instance, the researchers analyzed the 1998 OSTC Grade 3 section to locate keywords that reflect inclusion. This approach is supported by Winter and McClelland who wrote, "By the end of Grade 3, [students would] ask questions about and identify needs and problems related to structures and mechanisms in their immediate environment" (p. 77). This extract is also related to the Additive aspect of Banks's model.

In the following discussion, more examples are tabulated based on extracts from both the 1998 and 2007 OSTC.

Presentation of Findings

The Following table sets out extracts from the 1998 and 2007 versions of *The Ontario Curriculum, Grades 1–8: Science and Technology*. This table includes all the parts of the two versions of the OSTC that can be considered to satisfy one or more of the Banks-based assessment criteria. Each extract is associated with the applicable grade level or other section of the OSTC, as well as with the applicable Banks-based criterion or criteria. The table is followed by a brief overview of some of the most notable extracts from the two curricula.

As can be seen in the table, our examination of the 1998 version of the OSTC for Grades 1 to 8 contains at most two statements that might be interpreted as promoting diversity. The only statement that does so in an explicit manner is the requirement that students be able to describe different cultures' systems and structures relating to motion. Moreover, it is to be noted that the curriculum only mentions the contributions and achievements of Western scientists like, for instance, Archimedes, Bernoulli, and Pascal.

Table 1: Extracts from the OSTC 1998 and 2007 that Satisfy Banks's Principles of Multicultural Education

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
Grade 1	None	N/A	[. . .] 1.2 Assess ways in which daily and seasonal changes have an impact on society and the environment (e.g., [. . .] The Anishinaabe people [an Aboriginal group] tell their stories only in the winter when there is snow on the ground.) (OSTC, 2007, p. 54)	Additive
Grade 2	None	N/A	[. . .] 3.3 Identify ways in which animals are helpful to, and ways in which they meet the needs of, living things, including humans, to explain why humans should protect animals and the places where they live (e.g., [. . .] the buffalo provided some Aboriginal people with everything they needed to survive: food, shelter, clothing, tools, ornamentation, and weapons) (OSTC, 2007, p. 60)	Contributions

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
Grade 3	None	N/A	Growth and Changes in Plants focuses on the characteristics and requirements of plants and the ways in which plants grow. [. . .] Connections can also be made with the Grade 3 social studies topic Heritage and Citizenship: Early Settlements in Upper Canada, as students look at the types of plants that were used both by Aboriginal people and the settlers, plants that were native to the area, and plants that were introduced by the settlers. (OSTC, 2007, p. 70)	Additive
			1.1 Assess ways in which plants are important to humans and other living things, taking different points of view into consideration [. . .] *Sample prompts:* [. . .] Aboriginal people use plants for many medicines. (OSTC, 2007, p. 71)	Additive

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
			[. . .] 3.5 Describe ways in which humans from various cultures, including Aboriginal people, use plants for food, shelter, medicine, and clothing (e.g., food—from rice plants; houses for shelter—from the wood of trees; medicines—from herbs; clothing—from cotton plants) (OSTC, 2007, p. 72)	Contributions
			1.1 Assess effects of strong and stable structures on society and the environment (e.g., [. . .] strong and stable structures can endure for long periods of time and provide a historical record of other societies and cultures . . .) *Sample guiding questions:* [. . .] What features of structures such as old covered bridges, heritage homes, the Pyramids, and the Parthenon have enabled them to still be standing today? What can we learn about strength, stability, form, and function from studying these structures? (OSTC, 2007, p. 74)	Additive

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
			1.2 Assess the environmental impact of structures built by various animals and those built by humans *Sample guiding questions:* […] What effects do traditional Aboriginal homes have on the environment? (OSTC, 2007, p. 74)	Transforma-tion
Grade 4	None	N/A	None	N/A
Grade 5	None	N/A	[. . .] 1.2 Evaluate the impact of society and the environment on structures and mechanisms, taking different perspectives into account [. . .] *Sample issues:* […] People in the Far North have to construct buildings on ground that is permanently frozen just below the surface. If their buildings have normal foundations, the heat loss from them would melt the frozen ground and unsettle the structure. (OSTC, 2007, p. 102)	Additive

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
			2.2 Use scientific inquiry/research skills to investigate issues related to energy and resource conservation (e.g., interview an Aboriginal person about his or her traditional teachings on conservation) (OSTC, 2007, p. 108)	Transforma-tion
Grade 6	[…] describe how different devices and systems have been used by different cultures to meet similar needs (e.g., irrigation systems for farms, temporary shelters, bicycles). (OSTC, 1998, p. 83)	Additive	1.1 analyze a local issue related to biodiversity (e.g., the effects of human activities on urban biodiversity, flooding of traditional Aboriginal hunting and gathering areas as a result of dam construction), taking different points of view into consideration (e.g., the points of view of members of the local community, business owners, people concerned about the environment, mine owners, local First Nations, Métis, Inuit), propose action that can be taken to preserve biodiversity, and act on the proposal (OSTC, 2007, p. 113)	Social Action

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
	[…] identify and describe past and present-day contributions of astronomy to the quality of human life (e.g., development of the calendar; prediction of events such as eclipses and seasons; provision of information about space and time); (OSTC, 1998, p. 100)	Additive	1.1 Assess the short- and long-term environmental effects of the different ways in which electricity is generated in Canada (e.g., hydro, thermal, nuclear, wind, solar), including the effect of each method on natural resources and living things in the environment *Sample problems:* […] (b) The James Bay Hydroelectric Project was one of the biggest hydroelectric developments of the past century, but it has also had a serious impact on the environment and the James Bay Cree people. Investigate both sides of this issue, and suggest how things might be approached differently today. (OSTC, 2007, p. 119)	Social Action

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
Grade 7	None	N/A	[…] 3.9 Describe Aboriginal perspectives on sustainability and describe ways in which they can be used in habitat and wildlife management (e.g., the partnership between the Anishinabek Nation and the Ministry of Natural Resources for managing natural resources in Ontario) (OSTC, 2007, pp. 127–128)	Additive
Grade 8	None	N/A	[…] 3.1 Identify various types of systems (e.g., mechanical systems, body systems, optical systems, mass transit systems, Aboriginal clan systems, health care systems) (OSTC, 2007, p. 145)	Contri-butions

Grade Level	Extract from OSTC 1998	Banks-based Criterion	Extract from OSTC 2007	Banks-based Criterion
			[…] 1.2 Assess how various media sources […] address issues related to the impact of human activities on the long-term sustainability of local, national, or international water systems *Sample issues:* (c) The Protocol for Safe Drinking Water in First Nations Communities addresses drinking water concerns in First Nations communities. Various government agencies, news agencies, and interest groups have different perspectives on its development and release. (OSTC, 2007, p. 150)	Social Action

The 2007 version of the OSTC yielded at most 20 statements that might be construed as satisfying one or more of the above Banks criteria. This represents only a modest improvement over the 1998 version—both in terms of the number of diversity-related statements and in terms of their substance. Many of these statements are expressed at high levels of generality without supporting details or instructions. In some instances, the statement does not mention diversity at all but only makes a recommendation or observation that may or may not be construed as relating to diversity. In other words, the reader in these cases appears invited to "read in" a diversity-oriented message, but nothing more. For example, on page 8 the OSTC states that, "teachers bring enthusiasm and varied teaching and assessment approaches to the classroom, addressing individual students' needs and ensuring sound learning opportunities for every student."

It is noteworthy that the detailed statement of the curriculum's expectations and goals on page 11 fails to mention diversity at all. More specifically, it omits to mention the need for teachers to expose students to the diverse roots of scientific knowledge and to draw on the perspectives and experiences of a wide range of racial, ethnic, and cultural groups.

Despite the appearance of greater inclusiveness as a result of the addition of an "antidiscrimination" section, there are at most only two elements in this section that actively promote diversity—the first being the recommendation that schools reach out to parents and community members from diverse groups and the second being a group of abstract statements that discuss the idea of drawing on diverse perspectives in teaching scientific concepts.

The section on English-language learners appears to contain only one element that satisfies Banks's principles, this being the instruction that teachers tap into the students' collective breadth of background knowledge resulting from the racial, ethnic and cultural diversity in the classroom. On a more positive note, the 2007 version of the OSTC in several places highlights the scientific insights and contributions of Aboriginal peoples. An example is the requirement for students to describe Aboriginal perspectives on sustainability and the ways in which these can be applied. On the other hand, the curriculum makes little or no acknowledgement of some of the specific racial, ethnic, and cultural groups that have been added to the Canadian mosaic over the last several decades. One of the only tangential acknowledgements of non-European achievements in science and technology is the mention of the Pyramids on page 74.

Discussion and Analysis of Findings

Drawing on post-colonial theory, the principles articulated by McNay (2000), and especially Banks's criteria, our content analysis of the 1998 and 2007 versions of the science curriculum for Grades 1 to 8 has revealed a failure to ensure the teaching of scientific concepts and literacy in a manner that promotes the goals of multicultural and anti-discriminatory education.

One of the most important aspects of multicultural and anti-discriminatory education is to challenge the concept of "the other" by emphasizing our common humanity and, in particular, the ties that bind us together as human beings, in all our racial, ethnic, and cultural diversity. Regrettably, the authors of the Ontario science curriculum have not yet accepted their responsibility to be pro-active in combating "the tendency to dichotomize and generate a sense of *other* [by] working actively to confront the 'us and them' mentality that invariably sees 'us' as the norm, the desirable and the superior" (Hodson, 2003, p. 656). It is our contention that an indispensable part of confronting the "us and them" mentality is exposing students to the diverse roots of scientific knowledge and, in particular, to paths of scientific development that have over the centuries criss-crossed racial, ethnic, and cultural frontiers.

The 1998 OSTC makes few claims and even fewer attempts to advance the cause of multicultural and anti-discriminatory education. As explained above, this document only makes *three* statements that might be construed as satisfying at least one of Banks's four multicultural-education criteria. Other writers have also identified this failure, including Corson (2001) and Malekan (2008). Interestingly, Corson (2001, as cited in Malekan, 2008, p. 182) claimed that the "authors of the 1998 OSTC were advised 'not to mention words and phrases like "anti-racist," "multicultural," "equity," "culture," or anything else that might suggest a school system at all troubled by the systemic racism it contains' (p. 61)." In his analysis of the 1998 OSTC, Malekan (2008) observed that "the curriculum is a battleground for a power struggle over the promotion of certain values, beliefs and interests—and the exclusion of certain others" (p. 184). He emphasized that this exclusion is rooted in "hegemony and ideology" (p. 184).

In contrast to the 1998 OSTC, the authors of the 2007 version attempt to convey the impression that they understand Ontario's multicultural reality and that they seek to advance the principles of multicultural and anti-discriminatory education. According to the 2007 OSTC, the curriculum's expectations relating to anti-discriminatory education, violence prevention, and Native education have been incorporated where relevant. Moreover, the document has sections called "Antidiscriminatory Education" (pp. 36–37) and "Consideration for English Language Learners" (pp. 33–35).

Yet, despite these apparent improvements, the 2007 OSTC does not deliver on its heightened expectations. The curriculum does not make science instruction more inclusive for students of all backgrounds. More specifically, it fails to direct, convince, and equip teachers to demonstrate that virtually every race, ethnicity, and culture has made a vital contribution to the international body of scientific knowledge. For instance, in very few areas does the 2007 OSTC mention the scientific contributions of Aboriginal people, Muslims, Asians, or Africans. This act of omission represents a missed opportunity to foster greater understanding and respect among the many races, ethnicities, and cultures that comprise the Ontario student population as well as to provide encouragement to students from marginalized communities to pursue further studies—and ultimately careers—in science.

As first-generation Canadians, we believe that the Ontario science curriculum does not properly represent the ingenuity of the Canada's First Nations. Aboriginal peoples were particularly adept in applying the scientific method—that is, empirical observations followed by the extraction of inferences therefrom. Knowledge rooted in naturalist traditions is common to native communities, knowledge at which they arrived through observation and direct experience (Nelson-Barber & Estrin, 1995). Yet, notwithstanding the marginal increase in the number of references to Aboriginal peoples in the 2007 version relative to its predecessor, the OSTC continues to manifest a lack of commitment to presenting Aboriginal peoples in an accurate light, as well as to drawing on their scientific acumen. Indeed, the concerns of earlier researchers, that the "OSTC teaches students about the material culture without incorporating values and philosophies of the first nations people and therefore, rather than eliminating, actually perpetuates the stereotypes" (Ahmed, 2004, p. 10), continue to apply.

We agree with the view of many Canadian education scholars (e.g., Willinsky, 1998; Cummins, 1997; Hodson, 1993, 1996, 1998; Dei, 2000; and Shujah, 1999) that Canadian public school curricula typically make only a superficial attempt to embrace multiculturalism and thereby overlook the histories of the minority groups that together comprise the majority of the student population in Canada (as cited in Alghamdi, 2005, p. 242). Our assessment of the 1998 and 2007 science curriculum certainly echoes this view. Students with interests, knowledge, or skills that are not Eurocentric are not privileged by the science curriculum in the manner of those coming from a European background (Hodson, 2006; Malekan, 2008; McNay, 2000). As it stands, the curriculum contributes to maintaining the existing social order in the sense that power continues to rest with the dominant group—a key result being the continuing disempowerment and colonization of the new generation of students, who will be increasingly disengaged from their surroundings, environment, and schools.

Hence, despite whatever emancipatory illusions it may try to present, the Ontario science curriculum appears to be preoccupied with promoting, preserving, and perpetuating a scientific culture of uniformity, where students are "expected" to be encultured and assimilated into what it defines as science. In the absence of any socio-cultural context this is inherently Western science.

However, as other studies (e.g., Cobern, 1996; Hodson, 1993) suggest, we urge the adaptation of various constructivist approaches in which the emphasis is on using the learners' lives, experiences, and understandings as starting points for teaching subjects such as science. It is high time for historically marginalized voices to at last be brought to the centre of the curriculum. Only then will that curriculum be appropriate to the emerging generations of a multiethnic, multilingual, and multicultural Canada.

Conclusion

Despite making a number of improvements on its immediate predecessor, the Ontario Science and Technology Curriculum 2007 for Grades 1 to 8 largely fails to implement the principles of multicultural education. More specifically, it does not harness Banks's four approaches to multicultural education to ensure that all the major racial, ethnic, and cultural groups that comprise the Ontario population are reflected in and celebrated by the teaching of science. In particular, the 2007 OSTC neglects to direct, convince, and equip teachers to expose students to the diverse roots of scientific knowledge. This failure represents a missed opportunity to encourage students from marginalized communities to seriously consider further studies in science and, eventually, science-related careers. On a more general level, this failure represents a missed opportunity to foster greater respect and understanding between students of different backgrounds.

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