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Title: A New Consensus on Possible Future Orientations for Science Education in Canada: A Delphi Study (Part 2)

Abstract:

The recent Planetary Boundaries conceptual framework of the Stockholm Resilience Centre provides the basis for instituting a global effort to understand deeply the critical Earth systems upon which the endurance of human societies depends. The emergence of an Anthropocene Period of human activity similarly argues persuasively for humanity to appreciate its position as a high-impact species of geological and geochemical significance. Taken together, the present conditions provide fertility for considering a new vision of what it means to be educated in the sciences in succeeding generations. Any new vision for science education should account for the scales at which humanity and its science are currently operational and impactful. That is, the coupling of boundary conditions at planetary scales to the local and regional scales at which human development occurs creates conditions for education not required by previous societies. Reported here are the first results of a Delphi study of the expert community concerning the future of science education in Canada. The objective of the research was to empirically determine levels of consensus concerning the principal theoretical foundations and the effects of system conditions for the next generation of science education in Canada. The research was conducted through an online, anonymous, and futures-oriented modified Delphi methodology. Over a five-month period, an assembled expert panel derived from 130 peer-acknowledged, criteria-referenced, and representative science education specialists from Canada - comprising fourteen identifiable professional affiliations in two cohorts - participated in a Delphi having three rounds. The outcome of the research was setting priorities among 47 themes across five major domains together with a rich array of participant commentary. This first-of-kind study identified a number of consensus positions in accordance with standard statistical criteria held as customary in a Delphi approach. These
consensus positions occur across three principal areas expected to have high impact on Canadian science education in the coming decades: (1) identification of significant national and international globalization trends; (2) setting out the foundations and goals of science education; and; (3) describing the context for the future of science education in Canada. The findings of the study provide a new basis for, and constitute potential new challenges to, science education in Canada and argue persuasively for situating the sustainability of human societies within our planet’s systems as being central to the purposes of science education internationally. Sustainability Science, Technology, Economy and Environment (SSTEE) is presented as a guiding foundation for science education. This terminology constitutes a new tension for science curriculum development, and directly challenges (or complements) the rapid emergence of Science, Technology, Engineering and Mathematics (STEM) as a basis for science curriculum reform in the present international context.

**Keywords:** Canadian science education, science curriculum, modified Delphi study, STEM education, planetary boundaries, education for sustainability.
Discussion and Analysis

As identified earlier, the research conducted for this study sought contributions from the expert panel across four broad-scale questions, but the analysis here – for the sake of brevity - will confine itself to two of these: the influences of international trends, and; setting forth the foundations and goals for science education in Canada as its independent education systems face their varied, possible futures.

A more extensive treatment of the data from the complete suite of research questions is available in Murray (2014). Among the interpretations and observations in this section, certain selected commentary from the panel members is featured to provoke further thought and considerations beyond the scope of what is presented here.

Influences of International Trends on Canadian Science Education

Significant consensus was achieved for two important influences expected to predominate for science education in Canada: the perceived need for the development of 21st century skills (consensus level = 80.95%) and science and education for sustainability (consensus level = 71.43%). When the expert panel re-rated these same influences – but this time through the lens of what they viewed as their desired state of influence – more significance was placed on these two trends in terms of the importance of what should occur in systems of education in Canada: the development of 21st century skills (consensus level = 95.24%) and science and education for sustainability (consensus level = 92.86%; cf. Table 1). The high levels of consensus on the visibility of science and education for sustainability presents a very fresh set of conditions which could argue for a re-orientation of the very purposes of science education in Canada. Interestingly, the increased level of consensus on the development of 21st
century skills was driven in Rounds 2 and 3 by significant emphasis from COHORT 1 – those who are at early- to mid-career in science education or a professional discipline allied with the sciences. Two other trends emerged in terms of desired influences, these being: the relevance of science education to students (consensus level = 85.71%) and re-conceptualizing the purposes of science education (consensus level = 71.43%). An increased level of consensus on the relevance of science education was strongly driven in Round 3 by the opinions of COHORT 2 – the more experienced cohort. Both cohorts were similarly positioned with respect to consensus on the re-conceptualizing of the purposes of science education.

There was one notable negative consensus position (opposition) emerging from Rounds 2 and 3: that related to an expectation that the integration of Aboriginal/Indigenous perspectives in science education would not (or should not?) hold significance in the next 15-20 years. This situation showed itself to be a tension which survived all rounds of the Delphi. Indigenous perspectives were by no means absent from the commentary of participants. In Canada (and elsewhere where significant Indigenous populations are represented in the education system), Indigenous views are often considered important to the very character of a Canadian approach to science education (e.g., Aikenhead & Sutherland, 2015; Aikenhead & Elliott, 2010).

Approximately half of the expert panel was of the opinion that national and international standardized assessments of student achievement in science (e.g., PISA, TIMMS, etc.) would have some degree of importance as influences on future trends in science education. However, when asked about the degree to which such influences should have some importance, the voices were rather different. The general consensus was a significant rejection of the role that such assessments should have on influencing the directions of science education in the coming years. This negative opinion-making was directed more from panel members in COHORT 1 than in COHORT 2. This is potentially an important and significant finding given the current climate of Canadian education systems monitoring and the manner
in which numerical adjudications of student achievement are viewed in the political sphere as proxies for measuring the health of education systems. Such assessments have become an international preoccupation and are stimulating a lively debate about how educational success is or can be measured.

Foundations and Goals for Canadian Science Education

When assessing the foundations for Canadian science education, both the Round 2 and Round 3 questionnaires afforded the expert panel with this guidance on what was implied by a “foundation”:

“For the purposes of this study, ‘foundations’ refers to the large-scale aspects of a general science education that usually help to create frameworks from which science curriculums (curricula) are developed in the Canadian provinces. Alternatively, these foundations could be thought of as the explicit "bases" upon which science education rests and speaks to its various emphases.”

The panel’s consensus positions indicated that the following five foundations for Canadian science education have emerged as priority areas (in order of decreasing consensus levels):

(1) Science Education for Sustainability (consensus level = 92.86%);  
(2) Science, Technology, Society and the Environment (STSE) (consensus level = 92.86%);  
(3) Scientific Skills for the 21st Century (consensus level = 87.80%);  
(4) The Nature of Science (consensus level = 78.57%) and;  
(5) Scientific Knowledge (consensus level = 71.43%).

The last of these in the list – scientific knowledge – would not have reached the minimum level of consensus if it were not for the strong views on its incorporation from COHORT 2 which as a group held
A consensus level of 76.19 % in Round 2 which stabilized at 80.95% in Round 3. At no time did COHORT 1 rate scientific knowledge as ‘very important’ (4) or ‘essential’ (5) in the ratings beyond a 61.90% level of consensus. This is perhaps indicative of differences between the cohorts in what constitutes ‘scientific knowledge’ or how the term is defined and warrants further exploration.

When a comparison is made between the Round 2 responses (cf. Table ‘A’ in Appendix, Part 1) and what is presented for Round 3 (cf. Table ‘B’, Part 1), it will be noted that certain of the foundations areas had changed priority positions from Round 2 to Round 3. Based on participant requests, the foundation areas of Science Education for Global Citizenship and Interacting Natural and Human Systems were collapsed under the more comprehensive foundation of Science Education for Sustainability. This area – in the coded data – subsumed and incorporated interests such as the sustainability sciences, education for sustainable development, education for sustainability, and sustainability education. Participants were required to provide justification statements for their positions in the case of rating the foundations. For some there was real difficulty in determining which foundations have greatest importance, or, a sense that isolating foundation areas was no less of a problem than compartmentalizing the science disciplines. That is, the identification of foundation areas was a constraint in the realisation of a completely new vision for the purposes of science education.

The goals of science education, as defined for the expert panel members in the Round 2 and Round 3 questionnaires, were described in the following manner: “For the purposes of this study, ‘goals’ refers to the larger-scale desired outcomes of a general science education that usually define the overall purposes of conducting science education in the Canadian provinces. In this instance, the goals are confined to what could define the K-12 system of science education; these goals are intended to serve all avenues of adult life.” Therefore, in assessing the importance for inclusion in Canadian science education, the goals constitute the “end-rationale” of the enterprise of science education more
generally and K-12 (formal) science education in particular. The goals should assist any Canadian in answering the fundamental question, “What is the purpose of science education in Canadian schools?”

The data coming from Rounds 2 and 3 in the study provided for the following consensus positions in terms of the goals for science education in Canada. Rather strong consensus positions on goals has been provided by the panel in the following areas:

(1) Literacy in science-related issues (consensus level = 100.00%);
(2) Contribute to human health and well-being (consensus level = 88.10%);
(3) Develop a deep sense of wonder and curiosity; (consensus level = 83.33%);
(4) Sustaining Earth’s systems (consensus level = 80.95%);
(5) Life-long learning (consensus level = 78.05%), and;
(6) Citizenship in a global technological society. (consensus level = 73.81%);

Commentary from the expert panel indicated that many of these stated goals seem complementary to one another to the point of needing to be reorganised under more comprehensive categories. In particular, most recommendations of this type expressed a desire to take goal statements (2), (4), and (6) and organise these under a single goal which could be described as “sustainability practices”, “sustainability-oriented citizenship” or related terminologies. Since the goals of science education traditionally inform what the stated outcomes may (or will) be in the traditional undertaking of curriculum development, and should be a set of declarations about the ultimate purposes of the pursuit of science education, it is noteworthy that the expert panel has taken certain non-traditional positions as they forecasted. That is, the expert panel has provided, from its quite stark negative consensus positions some strong indications that science education in Canada does not (or perhaps should not) desire to include among its primary goals, the:

(1) Training of future scientists (consensus level = 28.57%), and;
(2) Pursuit of progressively higher levels of study (consensus level = 21.43%).

Two other goals – science education for economic competitiveness and scientific careers development – received low enough ratings to consider these as having marginal support from the panel. Over both Rounds 2 and 3, COHORT 2 held somewhat more favourable views as to the importance of science as preparation for being in the “science career pipeline” goals than did COHORT 1 (cf. Table 3). Taken together, a strong argument is presented for leaving the preparation of future Canadian scientists to the post-secondary institutions and other scientific agencies. So long as the foundations have been laid for advanced study in the K-12 formal education system, the same system could aspire to a very different set of priorities and goals.

Towards a New Vision for Science Education in Canada

Any study which seeks to engage expert opinion on forecasting the next generation of science education in Canada will, quite naturally, gaze at the regional landscapes which are shaped by educational control among its provinces and territories, but will also enlarge that view to consider how each region contributes to the national perspective and then outward internationally. More to the point, the complexion of Canadian communities is undergoing rapid change as is occurring elsewhere. Indeed, most would accept that the world has changed in often unexpected ways in the last 30 years, and science education had better consider a response while also demonstrating the character of resilience. This raises questions as to how best to serve the new Canadian and international dynamic. For this panel, Canada was observed to be defined, in part, by its vast geography and circumpolar position. These defining characteristics provided shape and substance to the kind of science education envisioned by the expert panel. FNMI perspectives on the Earth’s systems emerged as important to consider in any
discussion about the future of science education, especially from the standpoint of ensuring cultural voices in curriculum are heard and ensuring a culturally respectful and responsive curriculum.

**Discussion and Implications of the Delphi**

**New Consensus Positions for Canadian Science Education**

The outcomes of this study provide important new directions, novel goals, a re-statement of the robustness of traditional foundational areas in science curriculum, and potentially significant change to the current architecture in Canadian science education. The expert panel has positioned many of its priorities in such a way as to have some distinguishing features when compared to current developments among the OECD countries, but some “vital simultaneities” as well. For instance, elevating education for sustainability to the very core foundations of science teaching and learning mirrors one of the six pillars of the new national curriculum of Iceland (Ministry of Education, Science and Culture, 2012). Two examples of expert panel tensions with developments in North America would include the core values of STEM education and low levels of interest in the adoption of the American *Next Generation Science Standards* (National Research Council, 2012; Achieve Incorporated, 2010; 2013). The following consensus positions, which can be viewed alternatively as priority contributors, have been identified from the expert panel (at the ≥ 70% level):

A. Consensus on four significant national and international trends that are expected to have high impact of the future of Canadian science education namely: Science and Education for Sustainability, Developing Scientific-Oriented Skills, the Relevance of Science Education for Students, and Re-Conceptualizing the Purposes of Science Education;
B. Consensus on a set of foundations for the science curriculum in Canada, which are: Science Education for Sustainability; Science, Technology, Society, and the Environment; Scientific Skills for the 21st Century, and the Nature of Science;

C. Consensus on the principal goals for science education in Canada, including: Literacy in Science-Related Issues, Contributing to Human Health and Well-Being, Global Citizenship and Sustaining Earth’s Systems, and Life-Long Learning in a Technology-rich Society;

D. Consensus positions on: the roles and responsibilities of the stakeholders in science education; indicators for a Canadian approach in science education which accounts for: the circumpolar position of Canada; its Indigenous peoples and their unique relationship to knowledge-keeping and to the landscape; addressing the problematic situation of Canada’s Indigenous peoples as underrepresented in the post-secondary and professional pathways of the sciences and the desire for more inter-jurisdictional cooperation in science education.

The Sustainability Sciences – a New Paradigm for Science Education Internationally?

A selection of expert panel members from Cohort 2 indicated in their retrospective remarks on science curriculum emphases that Canada parted company about three decades ago with the enterprise of American science education with the advent of a strong curriculum emphasis more in alignment with Roberts’s VISION II – that is, literacy in socio-scientific issues. The movement was uniquely influenced by Canadian thinking and became a science curriculum commonplace internationally as Science, Technology, and Society (STS) science in the mid-1970’s. Within a decade of that time STS had become rather widely accepted despite its continuing struggles for status against the traditions of academic rationalism. In the 1990’s in Canada, the Pan-Canadian Science Framework (CMEC, 1997) adopted STSE as a major thread among its foundations by adding an overt set of connections to the ‘environment’ (the
“E”) to the STS original. For many science educators, STSE approaches had claimed important new curriculum territory in Canadian schools, but the tension between it and VISION 1 science education created a stubborn dichotomy which was likely never intended. In a sense, there are two influential curriculum traditions in science education in Canada, and these have been envisioned as metaphors for curriculum (MacPherson, 1997; 1999).

I suggest here a more ambitious and comprehensive model for science education in Canada and in other nations – particularly those which have a colonizing history of Indigenous peoples. It is a ternary system seeking for more than an intermediary consensus between Roberts’ VISIONS I and II. Such a system would operationalize three end-member visions for science education – inclusive of the Vision III science education of Aikenhead (2006; 2007). This third dimension could provide the rapprochement and détente between the traditionally polarised forces of academic science and socio-scientific approaches, and it may then be possible to envision an entirely new approach to science education in Canada which also includes a world view unique to the Indigenous sciences (see Figure 2 below). If we then include a principal focus or purpose for science education (the sustainability sciences), the orientation for science education, teaching, and learning then takes on a tetrahedral orientation. Originally applied to chemistry education by Mahaffy (2006) and extended to historical perspectives in the teaching of chemistry by Lewthwaite & Wiebe (2011), this fourth dimension of the model broadens to the enterprise of science education to look through the lens of the sustainability sciences for inspiration as to its goals and aspirations.
According to Clark and Dickson (2003), about a decade ago we were “witnessing the emergence of an array of increasingly vibrant movements to harness science and technology (S&T) in the quest for a transition towards sustainability” (p. 8059). Almost by definition, what was meant in their version of ‘sustainability’ was very simple – the reconciliation of society’s pace of development (the “anthropocentric”) with the planet’s environmental limits as a set of networked systems operating on the time scale of geology (the “bio-centric’). Sustainability science is not narrowly defined as environmental science but reminds us that to conduct any science outside of an environmental context is inconceivable. As Clark (2007) framed it, the dynamic interactions between nature and society mutually shape one another, and therefore sustainability science provides balanced attention to how
society alters the physical environment and its converse – how the state of the environment and
changes to that environment shape society. There is perhaps no clearer definition of sustainability
science than that offered by the National Research Council’s statement of 1999:

“Sustainability science is not an autonomous field for it is problem-oriented and
problem-driven and involves the application of scientific knowledge in ways that
“coproduce between academics and practitioners” [read science practitioners,
faculties of science education, and teachers of science]. It is a vibrant arena that is
bringing together scholarship and practice, global and local perspectives from North
and South, and disciplines across the natural and social sciences, engineering, and
medicine. Its scope of core questions, criteria for quality control, and membership
are always in substantial flux.” (NRC, 1999; p. 285; italics not in original)

The expert panel in this study has provided a comprehensive set of perspectives on the
necessity, value, and expedient with respect to the sustainability sciences. Examples of this orientation
towards science education for sustainability include: (a) being viewed as simultaneously expected and
desired to be a “defining influence” impacting science education in Canada; (b) to be a new foundation
area for science education; (c) the identification of literacy in science-related issues, human health and
well-being, and sustaining Earth’s systems as new goals for science education, and; (d) science education
for a sustainable future was characterised by > 90% of the expert panel as being among uniquely
Canadian contributions to international science education to 2030. Taken together, this orientation to
sustainability principles offers strength to the learning objectives described in the Education for
Sustainability “curriculum of transformation” advocated a decade ago by McDonald (2003). This expert
panel has now granted renewed credibility and status required to take the actions advocated by
McDonald more than a decade ago.

The Delphi panel assembled for this study has provided a strength of consensus in its advocacy
for the sustainability sciences at a level that argues for paradigmatic change in science education and for
new terminology to enter the literature. I can introduce this new terminology – Sustainability Science, Technology, Economy and Environment (SSTEE) – to be presented as a principal, guiding foundation for science education in Canada. The term provides historical continuity to the STSE movement which was an important Canadian contribution to science education internationally. The term also exemplifies the defining characteristics of educating for sustainability which have been advocated by McDonald (2003), Babiuk & Falkenberg (2010), Murray (2012), and Sims and Falkenberg (2013). Additionally, since we cannot imagine the economic sphere operating independently of the environmental factors which serve to sustain it, the interrelationships among economy, technological advancement, and the environment at all levels is strengthened by this terminology. SSTEE also stands to initiate healthy tensions alongside the influences provided by the recent emphasis of Science, Technology, Engineering and Mathematics (STEM) internationally; a potentially ill-defined educational slogan which tends to overemphasize and less than critically align its interests with economic globalization, the education of a new technocracy, and feeding a science employment pipeline. Science, Technology, Society and the Environment – for the expert community consulted in this study – can remain a hallmark and defining characteristic of what it means to have a Canadian approach to science education. It is also a hallmark of a science education oriented to the sustainability of humanity among its interacting systems. This curriculum emphasis can readily be incorporated into the new term SSTEE.

Conclusion

This study sought to resolve a core set of research questions which all converged on an attempt to answer a question which could be framed as, “What are the future possibilities for science education in Canada.....the very purposes of science education as we go forward?” By extension, this study also provides further questions such as, “What important new positions for discussion in the international forum are generated by these results?”. Far from being a parochial one, all countries are invested in
varying degrees in answering these questions or a similar ones. Aikenhead (1999) once made the claim that “all countries should answer their science education [curriculum] questions for themselves.”

The assembled expert panel provided a series of recommendations about the current context and climate for science education internationally, offered recommendations on its foundations and goals, and assessed the characteristics of a large circumpolar nation as these affect the teaching and learning of science. The study made use of a unique research methodology – a modified Delphi – to access the opinion-making of a diverse array of educational voices. The findings of the study revealed that Canadian jurisdictions should re-imagine their respective visions for science education but consider embracing a deeply embedded commonality – the reconciliation of the anthropocentric and the biocentric systems through a sustainability sciences foundation.

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References (Part 2)


