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Title: A New Consensus on Possible Future Orientations for Science Education in Canada: A Delphi Study (Part 1)

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, criterion-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.
Introduction

The Planetary Boundaries (PB) conceptual framework of the Stockholm Resilience Centre, including its most recent revisions and updating, provides the basis for instituting a global effort to understand deeply the critical Earth systems upon which the endurance of human societies depends (Rockström et al. 2009a,b; Steffen et al. 2015). The efforts to delineate the nine boundaries which provide a long-term “safe operating space for human societies” has attracted considerable focus on the PB concept among the spheres of governance, policy, and the economy but its conceptual basis has yet to reach the discourse of science education. 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 (Steffen, Crutzen and McNeill, 2007; Crutzen, 2002). In my view, an appreciation for the consequences of high-impact as a species on critical environmental and human-constructed systems demands a reconsideration of the very purposes of science education in the modern, international context. The above considerations, taken together with present conditions and quite possibly unknowable future conditions for human societies, provides fertility for the conception of a new vision of what it means to be educated in the sciences. Stated another way, the time is opportune to consider seriously the rationale for maintaining science education in systems of formal education in a recognizable form at a time when planetary-scale systems are experiencing unprecedented levels of stress due to human activities. In addition, systems of education in many parts of the world have enthusiastically embraced the substantial diversity of aspirations and goals which, collectively, act to provide definition to what it means to live sustainably on a planet having considerable human and natural resources but rapidly stressing the very systems upon which sustainable societies must be grounded (Griggs et al. 2013).
This article presents to the Manitoba graduate student and researcher communities the findings of a recent doctoral dissertation Delphi study conducted in Canada which sought to explicitly and 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 asynchronous modified Delphi methodology. Over a five-month period, an assembled expert panel derived from (N = 130) peer-acknowledged, criteria-referenced, and representative science education specialists from Canada participated in the Delphi having three rounds - comprising fourteen identifiable professional affiliations in two cohorts. The cohorts were designed to represent two distinct periods of professional activity with respect to the sciences and science education. One cohort could be described as a veteran group whose individuals had more than twenty years of professional experience to bring to bear on the questions of Canadian science education, and a second cohort just reaching their career midpoints.

The study was deemed opportune and timely across three principal areas of consideration – history, emergence, and Canadian context:

1) History: Canadian science education is at a point where the historic effort of the Science Council of Canada (SCC) which culminated in the 1984 release of *Science for Every Student: Educating Canadians for Tomorrow's World*, is now 30 years behind us (Orpwood, 1985; Orpwood and Souque, 1984; 1985; Science Council Canada, 1984 a;b;c); about 20 years have passed since the Council of Ministers of Education, Canada (CMEC) initiated the primarily bureaucratic process that resulted in the *Common Framework of Science Learning Outcomes K-12: Pan-Canadian Protocol for Collaboration on School Curriculum* (CMEC, 1997; hereafter...
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the Common Framework). This pan-Canadian effort resulted in a national consensus on a framework of science learning outcomes was unable to overcome the barriers presented by strong provincial responsibility for education and curriculum in Canada and ultimately failed to be a project unifying the vision for science education.

2) Emergence: The Next Generation Science Standards (Achieve Incorporated, 2010;2013; National Research Council (NRC), 2012) provides a characterization of science education driven strongly by corporatist, bureaucratic, and Science, Technology, Engineering and Mathematics (STEM) influences which are simultaneously commonplace in the science education discourse and being adopted rather uncritically by certain American states and their science educators.

3) Canadian context: Canada is a circumpolar nation with a relatively small population in G20 terms and in possession of ecosystems services on an immense scale due to its geographic extent; Canada is also home to a sensitive arctic environment, large Indigenous peoples’ communities, and participates in the international community amidst growing influences of neo-liberal economics, globalisation patterns, and its own growing fossil fuel imprint on the planet’s atmosphere.

Each of the three areas of consideration just mentioned holds the attention of an international audience by virtue of echoes in their respective countries and regions of the world. For instance, though the project described here was conducted in Canada, there was a recognition at the outset that much of what would come forward in the research would have potentially broader international appeal. The reason for this is partly historical insofar as many science curricula throughout the world for decades demonstrate common foundational aspects which can be traced to very influential document frameworks developed in nations such as Australia, Canada, New Zealand, the United Kingdom, and the United States (Alters, 1997). Point (1) above emphases this by virtue of a contrast: the efforts of the SCC
in the early 1980s in Canada were arguably the most influential up to that point in time in identifying unique contexts for Canadian science education but became a mere footnote to the Common Framework developed in the mid-1990s which had as its basis U.S. reform frameworks. Such framework influences which, on occasion, have been a response to perceived critical points in a nation’s position with respect to science and technology education have been known to extend their reach beyond their designated target audience. That is, to other countries’ science curricula which did not share the same reasons for entering into curriculum reform.

Point (2) above raises a tension about the influences and effects of science educational *sloganism* and the nature of science education moving deeper into 21st century learning. In respect to educational sloganism we are reminded of the seminal work on slogan systems in the manner of Komisar and McClellan (1961). Their issue with educational sloganism was principally due to a recognition that trends with monikers or acronyms were “systematically ambiguous”. Bybee (2010) indicated that the “associated ambiguity” of using the STEM slogan among policies, programs and practices in science education forces a necessary clarification of the *purpose* of STEM education which may prove elusive. According to Roberts (1983), science curriculum must have multivariate influences and an orientation that reconciles school science, the natural sciences, the nature of science, and the nature of history. Such a “logic of slogans” fosters a recognition that movements such as Science, Technology, Society, and the Environment (STSE), and STEM have contributed to, and can continue to contribute to, science education. The suggestion here is that any particular curriculum framework orientation may be deemed necessary by some, but is not a sufficient contributor in the absence of variety in visions for science education. Recent international efforts to gather current reporting on STEM has provided new insights from South Africa, Korea, China, Taiwan, Japan, Brazil, Canada, the U.S., the U.K., Australia, New Zealand, France, Finland, and the Russian Federation (Marginson, 2015; Freeman, Marginson and Tytler, 2015). This type of international reporting, particularly the freshness of attempts to address the lack of
world-wide policy information and programme participation in STEM, has become an area of importance given the energetic research in this area being conducted in Canada in recent years (Amgen Canada, 2012; Let’s Talk Science, 2014). Descriptions of 21st century learning are as myriad as the variety of articles which seek to delineate what the term implies. About a decade ago, Osborne (2007) argued that “the dominant form of science education that is common across the world rests on a set of values that have no merit”, a set of “arcane cultural norms” (p. 173). He further argued that the set of conditions needed for future practitioners of science were (and perhaps still remain) quite different than those of the future citizen. Continuing to make attempts through curriculum, pedagogy, and assessment to service both of these needs cannot possibly succeed. There is likely a certain level of agreement, perhaps even emerging international consensus, about what a truly effective and appropriate 21st century education in the sciences would entail, but I suggest that we run the risk of becoming entrained in another form of educational sloganism if we were to admit that we have arrived at a consensus position.

Point (3) holds importance internationally by virtue of the emphases currently being placed upon the relationship between culture and science education, notably in countries such as New Zealand, Australia, Canada, the U.S., and Japan. These nations, and others, have historically placed colonizing influences in education leaving a legacy where Indigenous peoples are subjected to dominant cultural influences within the curriculum, may well be in need of an alternative vision for STEM education where students “border cross into the sub-culture of the sciences” (Aikenhead and Sutherland, 2015; Aikenhead, 2006) and are struggling with the complexities of disproportionate institutional access, lower student success rates, and becoming an increasingly important segment of the Canadian population in economic terms (Freeman, Marginson and Tytler, 2015). Moreover, it is to be expected that culturally-responsive science curriculum and teaching will remain contentious in the discourses on science curriculum (Gondwe and Longnecker, 2014). In a country such as Canada, Indigenous perspectives and
worldviews have reached a position of explicit status in certain Canadian provincial science curricula and are inseparable from the identification of the aspirations of the country and the future of human rights in a federation of states (Weinrib and Jones, 2015).

**Connections to International Trends in Science Education**

Canadian science education policy today is rapidly moving in the direction of a STEM focus with its provinces embedded in the larger synthesis as a federation and also internationally. In a background consulting report prepared by Weinrib and Jones (2013) for the Australian Council of Learned Academies’ (ACOLA) volume, *Securing Australia’s Future STEM: Country Comparisons*, these authors provided a very favourable outlook for Canadian STEM education at the post-secondary levels of more advanced study. It recognised that Canada has the challenge of encouraging national science education initiatives but with no federal-level ministry to set the vision for science education or a mechanism to exert binding policy influences among the Canadian provinces. Their report did, however, identify the important and often influential roles played by external stakeholder organizations in Canada such as the CMEC (1997), the Council of Canadian Academies (CCA, 2012; 2014), and Amgen/Let’s Talk Science (Amgen, Inc., 2012). The ACOLA initiative has been summarized in a newly-released set of country comparisons in the edited volume titled ‘The Age of STEM’. In that collection, Freeman, Marginson and Tytler (2015) provide abundant evidence that STEM education is shaping policy-making in a diversity of nations around the world, and often in some very nation-specific or context-specific ways.

In a similar vein, the Canadian Council of Chief Executives released its brief, *Competing in the 21st Century Skills Race* (Orpwood, Schmidt & Jun, 2012), and noted that the proportion of Canadian students in STEM programs at the post-secondary levels was weak when compared with the robust 50% in the People’s Republic of China. Their analysis raised what the authors described as some “uncomfortable questions for Canadians”, such as:
• What are the skills that will enable Canada to compete successfully in the 21st century, and what institutional arrangements will ensure this?
• How can Canada develop educational policies and plans geared to national economic priorities when our Constitution gives the provinces and territories exclusive responsibility for education?
• What will it take to convince policy-makers and the public that education is an investment in our economic future (particularly for indigenous Canadians) and not merely a social cost?
• How will we meet the need for more scientists, engineers, and technologists when our post-secondary system is largely driven by student choice, and, when insufficient numbers of students seem inclined to pursue [STEM] careers?
• In what ways can schools, colleges, universities, libraries, museums and other institutions help to improve Canadian educational outcomes? (Orpwood, Schmidt & Jun, 2012; p. 4)

The first, second and fourth questions in this list essentially frame the problem of “what kind of science education is desirable for Canadian students?” and generated the research focus which guided the study described in this article. First, there was a need for a logic of consensus as to what constitutes “21st century skills” in the STEM system of education due to the continuing ill-definition of the term and the growing preponderance of STEM terminology in the Canadian science education literature; secondly, the stubborn dilemma of seeking after a Canada-wide consensus on science education for the next generation amidst the reality of tightly-held provincial jurisdictional control of Canada’s education systems, and; thirdly, what will characterise many of the trends, pressures, and priorities that will be the principal drivers of science education reform (or reconstruction) in Canada over the next generation? These and related questions formed the basis for the development of the study outlined here, and framed its structure and orientation. The next section of the article will provide a brief historical account of the Delphi technique as a research methodology and how its nature aligns with the study presented here.
The Use of the Delphi Approach as Method

The Delphi method of anonymous forecasting was originally developed under classified circumstances in the late 1950s by researchers at the RAND Corporation in California, becoming de-classified as a methodology only in the early 1960s. Two RAND researchers – Norman Dalkey and Olaf Helmer-Hirschberg – opened up the Delphi method to a broader forecasting community with their published account of how the U.S. Air Force came to understand (through the opinions of its experts) the number of atomic weapons necessary to reduce overall expenditures on conventional munitions by a prescribed amount – and to construct the scenario from the standpoint of a Soviet-era planner (Dalkey & Helmer-Hirschberg, 1963). In a 30-year retrospective on the use of Delphi (and looking ahead as the forecasting technique would demand), Linstone and Turoff (2011) provide their thoughts on the evolution of Delphi techniques and possibilities for its future. In their summary observations regarding the future of Delphi, they state that:

“The future of Delphi will be in collaborative organizational and community planning systems that are continuous, dispersed, and asynchronous.....it will replace the impact of controlled surveys as a mechanism of influencing various organizational and community decision processes. These will allow many thousands to participate or observe an ongoing planning process.” (p. 1718)

The Delphi approach is considered to be uniquely situated to the analysis of topics and issues for which there is little historical precedent (Martino, 1972), where rapidly changing events are occurring or are considered to be imminent (Patton, 2002), and those that have high levels of connectivity and complexity such as setting educational goals or constructing innovative curriculum (Sweigert and Schabacker, 1974). According to Franklin and Hart (2007) there are three interest areas for researchers who are seeking to collect and analyse the judgments of an expert community: a) to document and assess those judgments from the standpoint of the researcher also being among the expert community (Stewart, 2001; Powell, 2003); b) capture the areas of collective knowledge among professionals that
are often not verbalized or explored (Stewart and Shamdanasi, 1990), and; c) force new ideas to emerge about the topic. To these three areas of interest I would add a fourth – that of creating a novel learning experience among the panel of experts within the field of expertise under examination.

In essence, the Delphi approach seeks to allow for a complex problem to be addressed, anonymously, by a panel of selected ‘experts’ under the control of a researcher or project leader who guides the process. There are three features of the Delphi approach that are commonly included and distinguish it from other forms of group interrogative research, namely: 1) anonymous group interactions and responses to guiding questions or statements that have a future orientation; 2) multiple iterations of sharing group responses (often with associated feedback loops) and the creation of new questionnaires that refine the responses of previous rounds of questioning; and 3) presentation of the results to group members with a core set of descriptive statistical analyses (Cochran, 1983). Murry and Hammons (1995) identified four principal advantages of the Delphi approach in securing the opinions of experts:

• The Delphi process makes use of group decision-making techniques that involve experts in the field, thought to have greater validity than the opinions of individuals.

• The anonymity of the process (e.g., use of questionnaires) helps to avoid some of the problems associated with face-to-face groups: for instance deference to authority, specious persuasion techniques, oral facility, and reluctance to modify positions already known publicly, and group “bandwagon effects”.

• The consensus reached by the group (hopefully) reflects reasoned opinions because the Delphi process forces group members to consider only the problem at hand and provide written responses.

• The group of experts can be geographically separated from one another and render contributions at minimal cost to the researcher(s).

The above advantages can be considered as antidotes to the shortcomings and serious obstructions coming from face-to-face deliberations as outlined in Uhl (1983), including:
• Group opinion is highly influenced by dominant individuals who usually monopolise a discussion, with little correlation between verbosity and one’s actual knowledge of the subject matter under discussion;

• Much discussion in group situations, while having the external appearance of being problem-oriented, is either irrelevant or biased because it is usually more concerned with individual and group interests than with problem-solving, and;

• Individual judgment can be distorted by group pressures to conform (p. 82).

In order to determine at least a first-order justification for using Delphi in this study, it was important to identify in the literature an example of a Delphi study which shared strong connections to the design of this study, was related directly to science education, and also had sufficient peer acknowledgement. One of the best known Delphi studies of the last fifteen years in science education provided a more than sufficient model. This was the Delphi examining “ideas about the nature of science” of Osborne, Collins, Ratcliffe, Millar and Duschl (2003).

In discussing their use of a three-round Delphi design, certain disadvantages of the technique were identified by Osborne et al. alongside many of the advantages outlined earlier in this section. Among the perceived difficulties they identified, the following are pertinent to the present discussion:

(1) the length of the process (it generally requires about 6 to 8 months for the data collection phases); (2) the potential of the researcher to inordinately influence the questionnaire formulation, and; (3) the difficulty of assessing appropriately the expertise of the group since the participants never actually meet. In addition to these potential threats to research integrity in a Delphi approach we can add the following considerations: providing respondents with adequate guidance while avoiding undue direction, refining with justification the process of defining the qualities of a “science education expert”, selecting and maintaining the membership of the expert panel, and determining what the operational definition of panel consensus is to be.
The Research Objectives and Procedures

The central purpose of this study of science education in Canada was to engage an assembled ‘expert community’ of science educators, and those with deep interests and commitments to science education, to identify the purposes for Canadian science education going forward. To accomplish this principal objective, an expert panel was convened to participate in a Delphi forecasting exercise which sought to frame the problem in a way which capitalized on many of the advantages of the Delphi just described in the previous section. The study included a number of sub-objectives, but for the purposes of this article there will be a concentration on just two of these:

a. To describe and give definition to the education system conditions that will influence future developments in science education in Canada, and;

b. To determine and describe the principal foundations and goals for the future of science education with a view to changing curriculum emphases.

Choice of Expert Panel Members

During the period November to December, 2013, a list of candidate participants was assembled by accessing publicly available, online contact information across the following domains of professional activity in Canada:

- Senior civil servants in Ministries of Education in all Canadian Provinces and Territories responsible for science education
- Provincial science specialists in Ministries of Education in all Canadian Provinces and Territories; it was considered an asset if there was direct involvement as a lead for a provincial science curriculum project and/or demonstrated work on the 1997 CMEC Pan-Canadian Science Project (1995-1997)
- Past recipients (1993 to 2013) of a Canada Prime Minister’s Excellence in Teaching Certificate (at all grade levels K-12 where the recipient’s biography indicated a preference for the teaching of science)
The expert panel of participants was divided into two cohorts based on professional experience, and were to meet (at a minimum) one or more of the following criteria:

i. For COHORT 1, acknowledged as a member of at least one of the following science education communities in Canada: academic sciences (faculty or graduate student), provincial / territorial ministry of education as a science education specialist or director of curriculum, teacher-educator in a faculty of education, a science teacher having received a Prime Minister’s Certificate of Teaching Excellence, an instructor at a college of applied arts and technology, or active in the media for the purposes of the public understanding of science; all satisfied a need to be a practitioner in science education since the era of the early 1990s to the present and further identified by peer influences together with the researcher’s opinion as being a respected expert in the field of Canadian science education through a combination of publications, formal and informal presentations, noted contributions to schools, school divisions, curriculum and program development, or participation in organisations dedicated to the advancement of science teaching and learning.

ii. For COHORT 2, criteria were as in (i) above, but with the exception of having been a practitioner or researcher in the sciences, allied fields, or science education as early as the 1960s to the 1980s and in some cases to the present time;

iii. Presently employed, or having held direct experience in, one or more of the following:
   a. Provincial / Territorial science education specialist, curriculum consultant, director, officer, assistant deputy minister or deputy minister of a Canadian education ministry;
b. College or university faculty in science education or the related science specialties (e.g., engineering, applied sciences, etc.);
c. K-12 science education with having worked in science curriculum development deemed as an asset; in the case of practicing science teachers, all in COHORT 1 were sampled from those who held a Prime Minister’s Award for Teaching Excellence in the period 2004 to 2013; those in COHORT 2 were sampled from those who held a Prime Minister’s Award for Teaching Excellence Certificate in the period 1993 to 2003;
d. Science media and the public understanding of science;
e. Provided expertise or background studies to the Science Council of Canada study in the period 1980 – 1984;
f. Provided expertise to, or directly connected to decision-making in the development of the 1997 CMEC Pan-Canadian Common Framework for Science Learning Outcomes, K-12.

The final list of candidates for participation in the study (N=130) was comprised as follows in Figure 1 below:

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3 The total in this list slightly exceeds 130 as some individuals are included in more than one category.
Theme Generation in Round 1 of the Delphi

The nature of how a Delphi study is designed and the manner in which it is conducted and produces data encourages the reporting of results for each round. Put another way, what may appear to some as an over-emphasis on methodological aspects of the Delphi study is actually somewhat intentional. A choice has been made here, therefore, to allow the rounds of the Delphi to assist in building the larger picture towards possible futures in science education and accomplish this by treating the two cohorts involved as if they were eventual contributors to a larger, combined committee structure. It has been recommended by experienced Delphi study authors that the first-round questionnaire be quite open-ended in the initial phase of the data collection (e.g., Hasson et al., 2000; Keeney et al., 2006; Rieger, 1986; Ziglio, 1996). In Round 1 of this study, instructions were given to the expert panel cohorts to respond free-form to four general questions (and at a length of their choosing) that were intended to contextualize a basis for forecasting the nature of Canadian science education for the next generation. It was important in this opening round of the Delphi to not unnecessarily direct the expert panel in a material way nor provide the actual content of the research questions. According to Mitchell (1991), open-ended questions in the early stages of the Delphi “allows a panelist to utilize the intellectual apparatus that makes them expert and may reduce any feeling of underutilization” (p. 344). In addition, Mitchell viewed the incorporation of panelists’ responses into future Delphi round questionnaires as motivating in terms of their continuance and commitment to the research study – a form of “seeing themselves as the research unfolds” (p. 344). Ziglio (1996) deemed the first stages of the Delphi as “of crucial importance in understanding the aim of the Delphi exercise” (p. 9) and recommended individual contact with expert panelists and the provision to them of “appropriate background information on the technique” (p. 10). To fulfill Ziglio’s recommendation, all participants were provided a brief primer on the Delphi approach both in the initial invitation letter and in a follow-
up email communication. On occasion, just prior to Round 1 opening, a few individuals asked for quite
detailed clarification of how the study rounds would proceed and in some instances sought literature
references of past Delphi studies that would provide further background to their participation. Hence,
the Delphi as learning experience was underway.

Round 1 began January, 2014 with four “seed questions” offered for the consideration of the expert
panel members. Two of these questions are presented here as these will contribute to the present
discussion and analysis:

• **Question 1:** What, if any, significant global trends can you identify which could have effects on
the nature of science education in the next 15 years here in Canada? For each trend or issue
provided in your response, please give as clear a description as is possible of your views on its
probable effects on science education and (if possible) the magnitude of such effects.

• **Question 2:** What, if any, should be the principal foundations and goals of science education in
Canada for the next generation? For each response provided, please give as clear a description
of each idea you present as is possible, and state why each is important for education in the
Canadian society.

The range of response length to each of the ‘seed’ questions was expectedly variable, with some
individuals providing extensive treatment of the issues arising from the seed questions and taking
opportunity to clarify at some depth their commitments, their considered opinions, and their positions.

In all, respondents provided in excess of 47,000 words of text to be coded iteratively and reflexively in
order to identify the principal themes emergent in the data in this initial round. Once the four-week
period assigned to Round 1 responses came to a close, the first set of queries made use of NVivo 10™
computer assisted qualitative data analysis software (CAQDAS) from QSR International and techniques
developed for CAQDAS in the last decade (Bazeley, 2006; 2009; Bazeley & Jackson, 2013). This early
stage NVivo 10™ analysis provided textual associations of predominant keywords sorted into word clusters which could then be the subjects of a new set of associations comprising “node classifications”. Such word associations were critical in determining what the coding nodes would be for each individual response in Round 1. The results of these queries established the following seven most common node classifications across all responses to the seed questions:

Node Classifications – Global Trends Affecting Science Education

- Development of Science-Oriented Skills
- Science, Technology, Engineering and Mathematics (STEM)
- Sustainability and Sustainable Development
- Globalization and Neo-Liberalism
- Indigenous Perspectives and Knowledge
- Relevance of Science to Students
- New Learning Technologies

Node Classifications – Foundations and Goals for Science Education

- Science for Sustainability and Global Citizenship
- Science, Technology, Society and the Environment (STSE)
- The Nature of Scientific Practices
- Interacting Global Systems
- Scientific Skill Development

4 In this article, the term “Indigenous” includes, worldwide, the original inhabitants of a place and their descendants’ subjection to colonizing influences. It also follows the UN convention for the term. In Canada, the term “indigenous” includes peoples self-identifying as First Nations’, Inuit, and Métis and uses uppercase form in respect for how Indigenous scholars spell the term (Aikenhead et al., 2014).
• Literacy in Science-Related Issues and Scientific Literacy
• Science for Economic Competitiveness

These higher-level node classifications were then used to code the written responses to determine the principal themes emerging from this first phase of the data collection (Flanagan, 1954; Green et al., 2007; Sinkovics & Alfoldi, 2012). The five coding procedures described below became the basis for identifying the themes in the data:

a. Word frequency analyses were conducted for each of the four Round 1 seed questions across each of the expert panel participants in both cohorts individually (N = 30 and N=26).

b. If a particular term, phrase, or word association appeared repeatedly in a word frequency analysis from one participant, it was noted and coded for as a “node” in NVivo 10™; in addition, if a term, phrase, or word association had close similarity among a number of participant responses, that too was noted and coded as a “classification node”; all keywords and terminologies directly associated with the seed question wording were automatically eliminated from word frequency analyses through filtering.

c. These coded concepts, explanatory ideas, and phrases were considered as “emergent” point sources (i.e., nodes) in the data; each node was associated with a brief, written description so as to maintain consistency in the coding; clusters of similar nodes were grouped into categorical nodes that would eventually describe the themes in the Round 1 data.

d. Any node categories containing a minimum of 2 sources (a “source” is an individual respondent) and 2 references (a “reference” is a codeable item as identified in (b) above) were then provided a second pass by the researcher for re-coding; this second pass involved coding of individual responses across each of the two cohorts separately and another coding with all responses collated into a single text document (combined cohorts) – one document for each of the four Round 1 seed questions.

e. Any node references that reached a minimum of >75% coverage in terms of their emergence in the data (i.e., were observed to have coding in at least three of: (1) individual participant
responses, (2) aggregated responses within a cohort, (3) auto-coded responses from text analyses in NVivo10™, and (4) matrix coding in NVivo10™ using two or more similar concepts, explanatory ideas, or phrases (as outlined in (c) above).

In all, 29 themes were identified from the seed questions in Round 1 responses, and these were grouped by the author into three clusters in accordance with the research questions. As we will see, these themes provide the basis for the construction of rating scales which were used in the Round 2 questionnaire. The themes and clusters identified are as follows (in no specific order):

**Global Trends Affecting Future Science Education Cluster** (11 themes)

1. Science, Technology, Engineering & Mathematics (STEM)
2. Integration of Indigenous Perspectives / Knowledge
3. Developing Science-Oriented Skills
4. Science and Education for Sustainability
5. National/International Student Assessments (e.g., PISA, TIMMS)
6. New Learning Technologies
7. Relevance of Science Education to Students
8. National / International Standards
9. Science Education for Economic Competitiveness
10. Re-conceptualizing the Purposes of Science Education
11. Globalization of the International Community and Neo-Liberal Values

**The Foundations of Canadian Science Curriculum Cluster** (7 themes)

1. Science Education for Global Citizenship
2. Science Education for Sustainability
3. The Nature of Science
4. Science, Technology, Society and the Environment (STSE)
5. Interacting Systems and Systems Thinking
7. Scientific Knowledge

The Goals of Canadian Science Education Cluster (11 themes)

1. Democratic Citizenship in a Global Technological Society
2. Career-building for a Technological Society
3. Economic Competitiveness
4. Literacy in Science-Related Issues
5. Personal Character Development
6. Life-Long Learning
7. Contributions to Human Health and Well-Being
8. Training of Future Scientists
9. Developing a Deep Sense of Wonder and Curiosity
10. Pursuing Progressively Higher Levels of Study
11. Sustaining Earth's Systems

Round 2 of the Delphi

Prior to the distribution of the Round 2 questionnaire, all panel members received a summary of the themes generated in Round 1. The summary was delivered back to panel members as a form of controlled feedback typical of the Delphi approach. The format of the summary was an adaptation of similar techniques developed by Collins et al. (2001) and Osborne et al. (2003), and included the following components: (a) provisional large-scale theme titles; (b) a brief synopsis of the justification for emergence for each theme including a sampling of contextual comments tagged with alpha-numeric ID codes of participants, and; (3) direct quotations (again with attached ID codes) from participants which provided both representative and notable definition(s) to a particular theme.

In the Round 2 questionnaire, participants were asked to rate the importance, relevance, or influence of (as the case may be) for each of the themes generated in Round 1, usually on a 5-point Likert scale with '5' being of greatest relevance or importance, etc.. In order to clarify their intent, a
number of items required participants to justify their ratings and/or comment upon the item. In some cases, commentary was asked for with respect to the degree to which the wordings presented in the questionnaire items was representative of their understanding of that item. For example, when rating the 11 themes of the Global Trends Affecting Future Science Education cluster, panel members were asked to rate the items twice – first according to their perception of the actual affect on the future of science education, and then a second time assessing what they thought the desired affect should be. This was in accordance to similar procedures developed by Lewthwaite (2001; 2006) in his Science Curriculum Implementation Questionnaire (SCIQ) and Lewthwaite & Cuthbert (2008) in a study of teacher perceptions of science curriculum as case studies in a Canadian school district. When one considers probable and possible futures in science education, it was deemed important to make this distinction with respect to current international influences and vector forces.

Once Round 2 was completed online, detailed summary reports were generated and fed back into the expert panel cohorts. This time, the summaries included descriptive statistics (percentages, mean, median, standard deviation, variance, and interquartile ranges (Q3-Q1)) for each item rated in the questionnaire. Justification comments that were deemed representative either of notable departures from the consensus position or aligned with consensus were also provided to the panel. In order for participants to be prepared for the manner in which these statistical summaries would be organized, a between-round brief was prepared and sent to the expert panel ahead of the summary reports once online submission for Round 2 had ended. Contained in that information brief was: a description of what would be presented statistically and why; how means, medians, and variances were to be understood in terms of rating scale design and achieving consensus; samples of justification statements, and; notes about what to expect from item design in Round 3. This procedure for data organization and reporting to the expert panel is well-supported in the literature for Delphi studies (Hasson, Keeney & McKenna, 2000; Hsu & Sandford, 2007; Powell, 2003). Table ‘A’ (Appendix ‘A’).
provides a complete listing of the panel’s ratings (disaggregated by cohort) to the Round 2 items across all 29 themes in the three clusters.

Round 3 of the Delphi

In Round 3, as with the previous round, participants were asked to rate the importance, relevance, or influence of (as the case may be) each of the themes and contributors to Canadian science education as first rated in Round 2. Table B (Appendix ‘B’) provides a complete, disaggregated listing of the panel’s ratings to the Round 3 items across all themes. In order to provide a summary, Table 1 (this section) offers combined ratings of themes across both cohorts as if all panel members were contributing as a single grouping. Attrition was low in Round 3, with 42 members providing complete questionnaire responses. In order to clarify meaning or to now solidify expert panel members’ positions, certain of the items from Round 2 required participants to again provide justification for their ratings and/or render commentary. This was especially necessary if their position had changed from the previous round or remained in an outlier position. In other cases, optional commentary was encouraged from what had been articulated by panel members in Round 2. In this way, the researcher was afforded opportunity to more clearly identify positions that were representative of the emerging group understanding of a particular item or theme. As was done between Round 1 and Round 2, expert panel members were again provided a statistical summary and controlled feedback of anonymous supporting comments from Round 2 as a feed-in preparation for the final round.
Table 1 Combined consensus positions for COHORTS 1 and 2 after completion of Round 3.

<table>
<thead>
<tr>
<th>THEMES – GLOBAL TRENDS &amp; SCIENCE EDUCATION (Perceived Influence According to Expert Panel)</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>S.D.</th>
<th>Consensus Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing Skills for the 21st Century</td>
<td>4.24</td>
<td>4.0</td>
<td>4</td>
<td>0.77</td>
<td>80.95%</td>
</tr>
<tr>
<td>Science and Education for Sustainability</td>
<td>4.00</td>
<td>4.0</td>
<td>4</td>
<td>0.70</td>
<td>71.43%</td>
</tr>
<tr>
<td>New Learning Technologies</td>
<td>3.71</td>
<td>4.0</td>
<td>4</td>
<td>0.67</td>
<td>64.29%</td>
</tr>
<tr>
<td>Relevance of Science Education to Students</td>
<td>3.71</td>
<td>4.0</td>
<td>4</td>
<td>0.83</td>
<td>57.14%</td>
</tr>
<tr>
<td>National/International Student Assessments</td>
<td>3.56</td>
<td>3.0</td>
<td>3</td>
<td>0.79</td>
<td>51.28%</td>
</tr>
<tr>
<td>Globalization of the International Community</td>
<td>3.48</td>
<td>4.0</td>
<td>4</td>
<td>0.83</td>
<td>54.76%</td>
</tr>
<tr>
<td>National / International Standards</td>
<td>3.40</td>
<td>3.0</td>
<td>4</td>
<td>0.84</td>
<td>50.00%</td>
</tr>
<tr>
<td>Re-conceptualizing of Science Education</td>
<td>3.40</td>
<td>3.0</td>
<td>3</td>
<td>0.96</td>
<td>38.10%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THEMES – GLOBAL TRENDS &amp; SCIENCE EDUCATION (Desired Influence According to Expert Panel)</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>S.D.</th>
<th>Consensus Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and Education for Sustainability</td>
<td>4.52</td>
<td>5.0</td>
<td>5</td>
<td>0.63</td>
<td>92.86%</td>
</tr>
<tr>
<td>Developing Skills for the 21st Century</td>
<td>4.39</td>
<td>5.0</td>
<td>5</td>
<td>0.70</td>
<td>95.24%</td>
</tr>
<tr>
<td>Relevance of Science Education to Students</td>
<td>4.31</td>
<td>4.0</td>
<td>5</td>
<td>0.78</td>
<td>85.71%</td>
</tr>
<tr>
<td>Re-conceptualizing of Science Education</td>
<td>3.95</td>
<td>4.0</td>
<td>4</td>
<td>0.99</td>
<td>71.43%</td>
</tr>
<tr>
<td>New Learning Technologies</td>
<td>3.81</td>
<td>4.0</td>
<td>4</td>
<td>0.83</td>
<td>64.29%</td>
</tr>
<tr>
<td>Science, Technology, Engineering &amp; Mathematics (STEM)</td>
<td>3.73</td>
<td>4.0</td>
<td>3</td>
<td>0.93</td>
<td>62.50%</td>
</tr>
<tr>
<td>Globalization of the International Community</td>
<td>3.71</td>
<td>4.0</td>
<td>4</td>
<td>1.04</td>
<td>59.52%</td>
</tr>
<tr>
<td>Integration of Indigenous Perspectives / Knowledge</td>
<td>3.38</td>
<td>3.0</td>
<td>3</td>
<td>1.06</td>
<td>45.24%</td>
</tr>
<tr>
<td>Science Education for Economic Competitiveness</td>
<td>3.15</td>
<td>3.0</td>
<td>4</td>
<td>0.94</td>
<td>39.02%</td>
</tr>
<tr>
<td>National / International Standards</td>
<td>3.13</td>
<td>3.0</td>
<td>3</td>
<td>0.98</td>
<td>30.77%</td>
</tr>
<tr>
<td>National/International Student Assessments</td>
<td>2.90</td>
<td>3.0</td>
<td>3</td>
<td>0.85</td>
<td>20.51%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THEMES – FOUNDATIONS of SCIENCE EDUCATION</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>S.D.</th>
<th>Consensus Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Education for Sustainability</td>
<td>4.45</td>
<td>5.0</td>
<td>5</td>
<td>0.63</td>
<td>92.86%</td>
</tr>
<tr>
<td>Science, Technology, Society and the Environment (STSE)</td>
<td>4.33</td>
<td>4.0</td>
<td>4</td>
<td>0.61</td>
<td>92.86%</td>
</tr>
<tr>
<td>Scientific Skills for the 21st Century</td>
<td>4.22</td>
<td>4.0</td>
<td>4</td>
<td>0.72</td>
<td>87.80%</td>
</tr>
<tr>
<td>The Nature of Science</td>
<td>4.07</td>
<td>4.0</td>
<td>4</td>
<td>0.71</td>
<td>78.57%</td>
</tr>
<tr>
<td>Scientific Knowledge</td>
<td>3.88</td>
<td>4.0</td>
<td>4</td>
<td>0.67</td>
<td>71.43%</td>
</tr>
</tbody>
</table>
### COMBINED CONSENSUS - COHORTS 1 & 2 (N = 42)

#### THEME – GOALS of SCIENCE EDUCATION

<table>
<thead>
<tr>
<th>Theme</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
<th>S.D.</th>
<th>Consensus Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literacy in Science-Related Issues</td>
<td>4.45</td>
<td>4.0</td>
<td>4</td>
<td>0.50</td>
<td>100.00%</td>
</tr>
<tr>
<td>Sustaining Earth’s Systems</td>
<td>4.26</td>
<td>4.0</td>
<td>5</td>
<td>0.77</td>
<td>80.95%</td>
</tr>
<tr>
<td>Develop a Deep Sense of Wonder and Curiosity</td>
<td>4.19</td>
<td>4.0</td>
<td>4</td>
<td>0.71</td>
<td>83.33%</td>
</tr>
<tr>
<td>Contribute to Human Health and Well-Being</td>
<td>4.14</td>
<td>4.0</td>
<td>4</td>
<td>0.61</td>
<td>88.10%</td>
</tr>
<tr>
<td>Life-Long Learning</td>
<td>4.00</td>
<td>4.0</td>
<td>4</td>
<td>0.70</td>
<td>78.05%</td>
</tr>
<tr>
<td>Citizenship in a Global Technological Society</td>
<td>3.88</td>
<td>4.0</td>
<td>4</td>
<td>0.89</td>
<td>73.81%</td>
</tr>
<tr>
<td>Career-building for a Technological Society</td>
<td>3.48</td>
<td>3.0</td>
<td>3</td>
<td>0.74</td>
<td>45.24%</td>
</tr>
<tr>
<td>Training of Future Scientists</td>
<td>3.31</td>
<td>3.0</td>
<td>3</td>
<td>0.68</td>
<td>28.57%</td>
</tr>
<tr>
<td>Personal Character Development</td>
<td>3.26</td>
<td>3.0</td>
<td>3</td>
<td>0.66</td>
<td>35.71%</td>
</tr>
<tr>
<td>Economic Competitiveness</td>
<td>3.12</td>
<td>3.0</td>
<td>3</td>
<td>0.92</td>
<td>33.33%</td>
</tr>
<tr>
<td>Pursue Progressively Higher Levels of Study</td>
<td>3.12</td>
<td>3.0</td>
<td>3</td>
<td>0.71</td>
<td>21.43%</td>
</tr>
</tbody>
</table>
References (Part 1)


