A NEW LOGIC OF CONSENSUS ON THE FOUNDATIONS OF SCIENCE EDUCATION IN CANADA: RESULTS OF A DELPHI STUDY OF THE EXPERT COMMUNITY

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ABSTRACT: Despite episodes of identifiably Canadian influences on science education, the last six decades of science education in Canada has been a decidedly American experience – particularly from the standpoints of: 1) the foundational policy documents that have provided explicit impetus to periodic science curriculum reform in Canada; 2) the principal theoretical foundations, guiding assumptions, and goals of science education, and; 3) the development of curricular frameworks in Canadian provincial jurisdictions. Though admittedly contested, it will be argued here that the Canadian systems of science education operating in the provinces and territories have not had opportunity, historically, to engage with curriculum uniquely designed from a Canadian perspective that supplies broad and respected appeal to the context of Canadian society, its demographics, its geographic diversity, and its geo-political position internationally.

The objective of the research design for this new look at science education in Canada was to empirically determine, and provide definition to, the principal theoretical foundations and system conditions for a Canadian approach to science education. Responsibility for this determination and definition rested with an assembled expert community. The research was conducted through an online, anonymous, and asynchronous modified Delphi methodology. Over a five-month period, the assembled expert panel of 54 peer-acknowledged and representative science and education specialists from Canada - comprising fourteen identifiable professional affiliations in two cohorts - participated in a Delphi having three rounds. This first-of-kind Delphi identified consensus positions in accordance with standard statistical criteria developed in the research design. These consensus positions occur across four principal areas of impact on the future of Canadian science education: (1) significant national and international globalization trends; (2) the foundations and goals of science education; (3) the roles and responsibilities of stakeholders in curriculum, and; (4) a context for the future of science education in Canada.

RESUMÉ: Malgré quelques périodes d'influences canadiennes identifiables, l'enseignement des sciences de la nature au Canada durant les six dernières décennies a été une expérience plutôt américaine, surtout au niveau : 1) des documents de politique fondamentaux qui ont mené aux réformes curriculaires en sciences de la nature au Canada; 2) des fondements théoriques principaux, des principes directeurs et des buts de l'enseignement des sciences et 3) de l'élaboration de cadres curriculaires dans les juridictions provinciales canadiennes. Quoique l'idée soit certes contestée, cet article fera valoir que les systèmes éducatifs dans les provinces et les territoires du Canada n'ont pas eu l'occasion, historiquement, de s'engager dans l'élaboration de programmes d'études particulièrement canadiens et donc pertinents pour le contexte de la société canadienne – son profil démographique, sa diversité géographique et sa position géopolitique.

Le but de la méthodologie de recherche pour cette nouvelle analyse de l'enseignement des sciences au Canada était d'établir et définir de façon empirique les principaux fondements théoriques et les conditions systémiques nécessaires au développement d'une approche canadienne à l'enseignement des sciences de la nature. Une communauté d'experts a été assemblée pour l'identification et la définition de ces fondements théoriques et ces conditions systémiques. La recherche a pris la forme d'un processus Delphi modifié, mené en ligne de façon asynchrone et anonyme. Sur une période de cinq mois, un panel d'experts comptant 54 membres, formant un échantillon représentatif de spécialistes canadiens en sciences de la nature et en éducation, a participé à un processus de Delphi comprenant trois rondes. Ce processus a permis de faire ressortir des consensus en fonction de critères statistiques normalisés développés avec la méthodologie de recherche. Ces consensus ont été classés selon quatre domaines pouvant avoir un impact possible sur l'avenir de l'enseignement des sciences de la nature au Canada : (1) les tendances nationales et internationales importantes; (2) les principes de base et les buts de l'enseignement des sciences de la nature; (3) les rôles et responsabilités des intervenants quant aux programmes d'études, et; (4) un contexte pour l'avenir de l'enseignement des sciences de la nature au Canada.

KEYWORDS: Canadian science education, curriculum, modified Delphi study, policy Delphi, expert panel.

Introduction

The last six decades of Canadian science education could be viewed as a decidedly American experience – particularly from the standpoints of: 1) the foundational policy documents that eventually provide impetus to periodic science curriculum reform in Canada; 2) the principal theoretical foundations, guiding assumptions, and goals of science education in Canada, and; 3) the development of curricular frameworks in Canadian provincial jurisdictions. Though controversial, it is argued here that Canadian schools, teachers, and students of science education have not had opportunity historically to engage with curriculum uniquely from Canada that supplies broad and respected appeal to the context of Canadian society, its demographics, and geographic diversity, and its position internationally as a circumpolar nation of growing influence. The research design of the study discussed here intended to bring to the surface the intentions, orientations, aspirations, and logic of a new consensus defining a Canadian science education. The timing of the study was opportune. For the science education community in Canada, the outcomes of the study could be of significance as we go forward.

We are at a point where the historic effort of the Science Council of Canada (SCC), culminating in the 1984 release of Science for Every Student: Educating Canadians for Tomorrow's World, is now 30 years behind us (Orpwood, 1983; 1985; Orpwood & Souque, 1984; 1985; SCC, 1984 a;b;c). In addition, some 20 years have passed since the Council of Ministers of Education, Canada initiated the process that resulted in the Common Framework of Science Learning Outcomes K-12: Pan-Canadian Protocol for Collaboration on School Curriculum (CMEC, 1997; hereafter the Common Framework). In practical terms, this pan-Canadian effort toward a national consensus on a framework of science learning outcomes was unable to overcome the barriers presented by provincial responsibility for education and curriculum in Canada. As a result, the implementation of the Common Framework fragmented into a situation where some jurisdictions embraced it in earnest and immediately, others hesitated for reasons of existing curriculum policy, and one key province (Québec) abstained from the process altogether from its inception.

In a recent collaboration between the Amgen® Canada Corporation and Let's Talk Science (a Canadian NGO which advocates for science learning), a survey of Canadian youth aged 16 to 18 was conducted to assess the level of student engagement in science. That assessment appeared as Spotlight on Science Learning – A Benchmark of Canadian Talent (Amgen Canada, Inc., 2012). This collaboration emerged from the 2010 Let's Talk Science® national survey which measured the desire of Canadian youth to pursue post-secondary studies in science, technology, engineering, or mathematics (STEM) disciplines. In Spotlight there was demonstrated a clear disconnect between students' perceptions of the importance of science in Canadians' lives and their degree of interest in its subject matter as an academic discipline. The project further claimed that greater than 90% of Canadian adults view youth engagement in science as a positive if not essential ingredient for national prosperity. These are the same perceptions and viewpoints expressed as far back as the late 1950s in the wake of concern over falling behind the Soviet Union's emerging technocracy (Tomkins, 1986). A ten-member expert panel of Canadians – convened in 2011 by Amgen Canada and Let's Talk Science® – met on three occasions to review data, determine STEM benchmarks, and make recommendations. This expert panel was by invitation, and comprised academics, knowledge economy specialists, science journalists, science educators, youth science learning advocates, and industry R&D leaders. The sources of data provided to the Amgen Canada study came from a variety of sources, including: the OECD, the Pan-Canadian Assessment Program (PCAP), provincial ministries of education across Canada, Statistics Canada, and the federal-level Human Resources and Skills Development Canada department.

This inquiry led to the position that Canada's progress in advancing STEM learning could be benchmarked by the following: 1) student performance on national and international science and mathematics assessments; 2) numbers of students entering post-secondary STEM programs and graduation at all levels; 3) STEM-related employment prospects; 4) Canada's international position with respect to numbers of graduates, and; 5) a suite of indicators intended to measure a "science culture" in Canada (Amgen Canada, 2012; p. 6). The panel's report used language that has become familiar in many of the periodic science education policy reform initiatives of the last 60 years such as "challenge", "economic well-being", "quality of life", "international competitiveness" and "achievement of excellence".

A recent report prepared by Weinrib and Jones (2013) for the Australian Council of Learned Academies provided a very favourable outlook for Canadian STEM education at the post-secondary levels. It too recognised the challenge of encouraging national science education initiatives in Canada with no federal ministry of education or the mechanism to exert binding policy influences among the 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 (2012), and Amgen/Let's Talk Science (Amgen, Inc., 2012). The study described in this review summary sought to bring together representatives from three principal interest groups in relation to the future of science education in Canada – Provincial Ministries of Education and their science education staff; academics from the sciences and faculties of education, and; NGOs who constitute vital linkages among those in the political, economic, and educational spheres of influence. This composite representation is similar to that garnered by the Council of Canadian Academies recently in a national study of the state of science culture in Canada (CCA, 2014). But first, however, it is important to look back about a generation to refresh ourselves of the last time there was considerable interest in describing science education on our own terms.

Seeking A Canadian Context for Science Education – The 1980's

The last episode of looking in-depth at the state of science education in Canada took shape in the late 1970s and the early 1980s. That period almost certainly received some inspiration from the Symons Report of the Commission on Canadian Studies which had been released in 1975. The Commission was established at the annual meeting of the Association of Universities and Colleges of Canada at Winnipeg, Manitoba in 1970. The title of the report of the Symons' Commission was very telling – To Know Ourselves – and it is somewhat apropos to the discussion to review it here. The title of the Commission report suggested that we recall the Delphic maxim from Plato in the Republic that to 'know thyself' transcends the individual and relates also to the life of the individual functioning in the larger society.

In the preamble to Symons' report, the Commissioner himself states: "The most valid and compelling argument for Canadian studies is the importance of self-knowledge, the need to know and understand ourselves; to know ourselves we must have an understanding and appreciation of the enormously important role played by science in our lives and in the formulation of our values and viewpoints" (Symons, 1975; p. 1). In the Report Rationale section of the report, we read a daring and explicitly patriotic statement that can only be understood in the context of the times: "Canada provides a North American alternative to life under the government of the United States" (p. 20). Since the Symons Commission was conceived just three years after the Canadian centennial year, it is no surprise that nationalist sentiment runs deep in this account of the state of the Canadian education system. The report identified such an urgent need to focus more intently on the perceived lack of a Canadian perspective in science education and technology that it devotes an entire chapter to this one discipline area alone. Fully thirty-four of the 144 pages in the Commission report addressed specifically the sciences and related technology fields. This occurred within a treatment of the Canadian education system which devoted itself to a broad swath of curriculum areas.

Bearing the sub-title, Is There a Canadian Science?, a subsection of the Commission report provoked a spirited debate among the Canadian scientific communities with the suggestion that the universality of scientific achievement might also bear the marks of a cultural and uniquely Canadian character. The consensus position from Symons' point of view portrays a viewpoint shared by many at the time: ......"science in Canada can be simultaneously international and Canadian in the sense that it is approached from a Canadian viewpoint, it fulfils a particular Canadian need, or it is related to a particular Canadian interest aroused by location, geography, climate or by some other distinct feature of the country." (AUCC, Symons Commission, 1975; p. 143). An additional influence at this time was the background paper prepared by James Page for the Science Education Study (SES) conducted by The Science Council of Canada, A Canadian Context for Science Education (Page, 1979). This brief summarized issues and concerns discussed by participants in a colloquium on the content in Canadian science education. The meeting was prompted by the (Symons) Report of the Commission on Canadian Studies which had indicated, among its other findings, that Canadian scientists and technologists fail to take into account the unique nature of Canada when doing their work, in all likelihood by virtue of the character of their own science education and professional formation.

Five major issues (defined as problem areas) were identified during the session facilitated by Page and appeared in his synopsis of the proceedings (Page, 1981): (1) the lack of attention to Canadian dimensions and problems in science teaching and research; (2) the failure of Canadians to recognize that science and technology are integral parts of our society's culture; (3) the need for increased public awareness of the roles played by science and technology in Canada; (4) the attitudes of young people toward science and technology, and; (5) a particular criticism of the neglect of the history of science in Canada as a discipline of academic quality and one holding interest among Canadian universities and federal granting agencies. It is rather a poignant curiosity that it was an historian – not a Canadian science educator – who was tasked with responding to the Symons report and assembling the colloquium to discuss its implications for science education in Canada.

In the early 1980s, a series of Background Papers were commissioned to inform the emerging SES national study of science education in Canada. Led by Graham Orpwood, the Oxford alumnus Science Advisor to the Science Council of Canada, the SES sought to frame – with a focus on teachers of science and the many stakeholders who advise the formal education system – a future course for science education by characterizing its present state. As the SES was getting underway with its signature episodes of deliberative inquiry in all ten Canadian provinces, there were seven background discussion papers developed by leading science education specialists for the Science Council of Canada in order to inform the national study. Taken together, these papers possess a certain purposeful dissonance created by the writers of the collection. Each paper considered a unique aspect of what constituted education in science as appropriate to a Canadian citizen at the time. None of the authors of the papers were required to be in agreement with another's position, nor did they have to, as the collection was not designed around that purpose. The chief purpose of the background papers was multiple perspectives on certain key issues of importance in Canadian science education with a view to providing impetus for public debate and consensus-building.

These background papers were by invitation and were designed to engage these multiple perspectives and were (arguably) typical of scholarly collaboration in Canada – respectful, insightful, and establishing diverse views. In addition to Page's generalist paper on the Canadian context for science education there were the following thematic contributions: Glen Aikenhead speaking to the failure of science education in Canada in addressing the social implications of science (Aikenhead, 1980); Donald George on the lack of attention paid to the skills of the Canadian engineer (George, 1981); Hugh Munby on the tendency of students to become intellectually and practically dependent on teachers (Munby, 1982); Marcel Risi on the inadequacy of teaching science as only a body of discipline-based knowledge instead of through a trans-disciplinary matrix which he described as "an ecology of the crossroads" (Risi, 1982); Robert Nadeau and Jacques Desautels on the dangers of treating science as a kind of religion, identified by them as "scientism" (Nadeau & Desautels, 1984) and; Douglas Roberts on "emphases in science education", the logic of educational slogans, and the "two senses" of science literacy as an aging slogan (as outlined by G. Orpwood in the forward to Roberts' paper (1983)). In my opinion, there is no better treatment of educational sloganism and its potential for threat or opportunity than Roberts' contribution to the debate about science literacy.

The consensus which was sought in the Science Education Study was an ambitious undertaking, especially given the constitutional provisions in Canada which often exert tight provincial control over education in the federation. By virtue of teaming with his co-lead investigator – Jean-Pascal Souque – and cultivating strong connections to leading figures in Québec, Orpwood managed a rare rapprochement in educational research in Canada. The Science Council's final report – Science Education in Canadian Schools: Educating Canadians for Tomorrow's World – provided a first-of-kind framework for science teaching and learning which had been the product of an exhaustive series of deliberative conferences across the country. Such a consensus had never been achieved before, and was never to be garnered again in science education in a manner similar to the series of face-to-face deliberative inquiry sessions held across Canada (Orpwood, 1983, 1985; Orpwood & Souque, 1984, 1985).

Taken together, the foregoing conditions of three decades ago aided immensely in providing a firm foundation to one guiding assumption of mine, and for the study outlined here. It is conjectured that Canadian science education can be characterized as a special case of a derived curriculum which comes not from ourselves and from within our own educational thought, but principally from external influences over which we may have limited influence and control. Moreover, when we reached the 1990s and beyond – the era of the Pan-Canadian Science Framework (CMEC, 1997) – the next period of significant increase in resources expenditure and Canadian educator involvement in science curriculum, this special case of the derivative curriculum remained stubborn, persistent, and actually repeated itself.

The Purpose of the Canadian Study and the Research Questions

In Canada today – as in many other OECD countries – discussions about the relationships among science education, science curriculum, defining '21st century skills', connections to economic considerations, and international rankings are surfacing on many fronts (see Amgen, 2012; Orpwood, Schmidt & Jun, 2012; UNESCO & Fensham, 2008). It can be readily demonstrated that periodic concern about the state of science education, youth readiness and fitness for the state of the world economy, and international competitiveness has occurred more than once in the last 60 years. Each time, a crisis situation in education has been identified and each time the evidence for a crisis was not entirely warranted. Ministries of education, school districts, teachers, and students – all of whom are somewhat 'protected' as insiders in education – sense external pressures on the development and implementation of curriculum and are asked to respond to the demands of influential external stakeholders. It is more than an idle curiosity to observe, or to at least offer speculation, that groups which are actually tasked with fulfilling accountability in the education system often become respondents to – and not the initiators of – educational reform.

The central purpose of this science education in Canada study was to identify the system conditions and principal theoretical foundations to develop a Canadian consensus on science education in the post-Pan Canadian Science Framework period. Essentially, an expert panel was consulted and engaged in forecasting to the year 2030. The study included the following sub-objectives:

a. To give definition to and describe in some detail the system conditions that will initiate and influence development of science education in Canada to 2030;
b. To determine and describe the theoretical foundations and goals for future science curriculum in Canada, and;
c. Provide for a characterization and establishment – a 'logic of consensus' – in Canadian science education from the contributions of an expert panel working anonymously.

These objectives were researched and documented through a lengthy, online, anonymous, consensus-oriented and asynchronous process of inquiry. The research was conducted exclusively in an online environment. The inquiry approach used in the study was a variant of the hybrid Delphi of Landeta, Barrutia & Lertxundi, (2011). The study was conducted over a five-month period among an assembled community of science and science education specialists from many parts of Canada. The following primary question and its ancillary questions guided the research:

Primary Research Question:

According to the perceptions of an assembled 'expert community' of science educators and those with deep interests and commitments to science education, what are the principal theoretical foundations, guiding assumptions, and purposes for Canadian science education which can be forecasted to the year 2030?

Ancillary Research Questions:

1. What trends and conditions – both domestic and international – will serve to initiate and have defining influence upon future science curriculum change in Canada?

2. What characterizes consensus (or disagreement / dissensus) among an expert community with interests and expertise in science education with respect to forecasting and defining the foundations and goals of the science curriculum in Canada?
3. What characterizes consensus on a Canadian vision for science education to 2030 in terms of distinguishing characteristics unique to Canada and the roles and responsibilities, and relationships among, the stakeholder community?

Sample Description and Methodology of the Study

This section provides a summary of the research design and methodology using a modified Delphi technique, followed in a subsequent section by procedures for data collection and analysis. Historically, the Delphi method has been used by researchers to collect expert opinion and analysis – particularly for the purposes of forecasting future trends or the effects of changes to existing systems. Delphi approaches are particularly attractive toward the achievement of consensus opinion or positions in relation to an issue that would otherwise be difficult to obtain through more direct, deliberative, and face-to-face interaction (Clayton, 1997). This study made use of expert opinion among individuals who share a diversity of interests in the enterprise of science education from across Canada. The participants comprised two distinct cohorts of specialists – one a veteran group with each having more than 25 years of experience and a second group approaching mid-career - that together constituted an expert panel. Their principal purpose was to provide expertise and forecasting to establishing the important trends affecting the foundations and goals for the future of science education in Canada to 2030.

Why 2030? The date is somewhat arbitrary in that a child born in 2014 will reach the end of a compulsory education in most Canadian jurisdictions by the year 2030. And so, the assembly of an expert panel which was tasked with forecasting what the science learning environment could look like over that span of formal schooling was neither a trivial pre-occupation nor was it expected to be accomplished with ease. Participation in a Delphi study involves an intense commitment over many months among the participants, and this study was the beneficiary of exemplary levels of dedication and expenditure of time and idea-making. During the period November, 2013 to December, 2013, a list of candidate participants was assembled by accessing publicly available, online contact information across the following domains of professional activity:

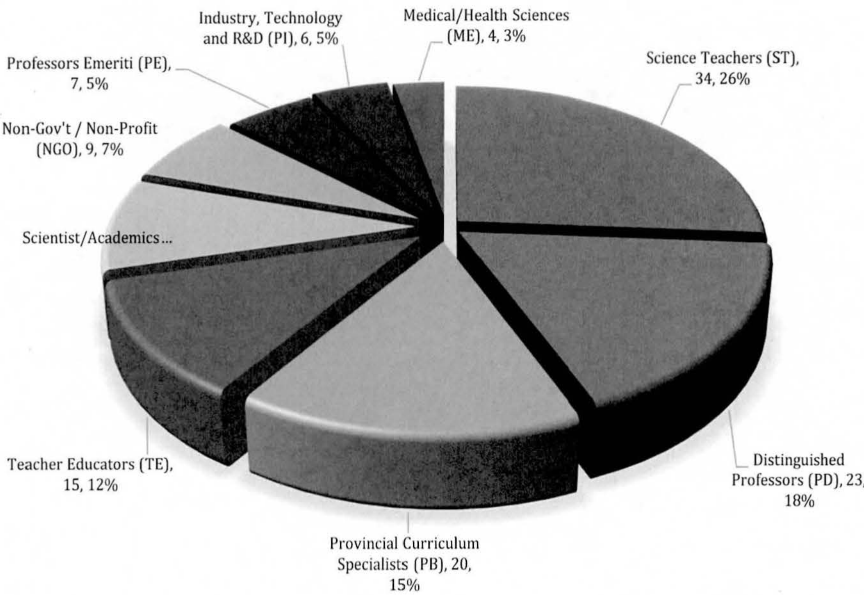
- Senior civil servants in Ministries of Education in all Canadian Provinces and Territories responsible for science education.
- Provincial science specialists in Ministries of Education in all Canadian Provinces and Territories; it was considered an asset if there was direct involvement as a lead for 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 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 Council of Canadian Academies' Expert Panels working on current assessments or those completed since 2008.
- The Canadian Space Agency's astronaut corps (active and retired).
- Researchers who worked on the Science Council of Canada study (1981-1984) or authored Background Papers for the Council's efforts.
- Deans of Canadian university medical schools.
- Teacher-educators in faculties of education in Canadian college or university settings.
- A randomized selection from among Tier 1 and Tier 2 NSERC / SSHRCC Canada Research Chairs in the natural sciences, science education, and engineering generally

representative of dispersion in Canada (N = 830 in random sample where N(selected) = 20).

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

- K-12 Science Teachers (N = 34)
- Distinguished Professors (N = 23)
- Provincial Ministry Science Curriculum Specialists (N = 20)
- Teacher-Educators in Faculties of Education (N = 15)
- Academic Scientists (N = 12)
- Non-Governmental Organisations (N = 9)
- Professors emeriti (N = 7)
- Public Understanding of Science/Outreach/Media (N=3)
- R&D, Industry, and Emerging Technologies (N = 6)
- Medical and Health Sciences (N = 4)

Figure 1. Invited Candidates by Professional Affiliation (N=130). 2

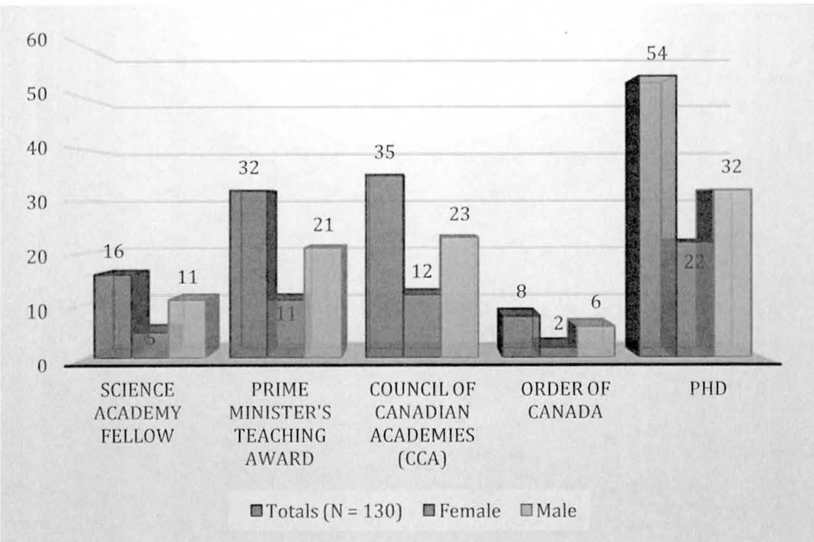


[1] The total in this list exceeds N=130 as some individuals are included in more than one category; the purposes for this are detailed later in this chapter.

2 The acronyms (e.g., PB, TE, etc.) denote professional affiliations that will be used throughout the remainder of the document. On occasion, these will be part of an alphanumeric code that uniquely identifies a contribution to the data by an individual (anonymous).

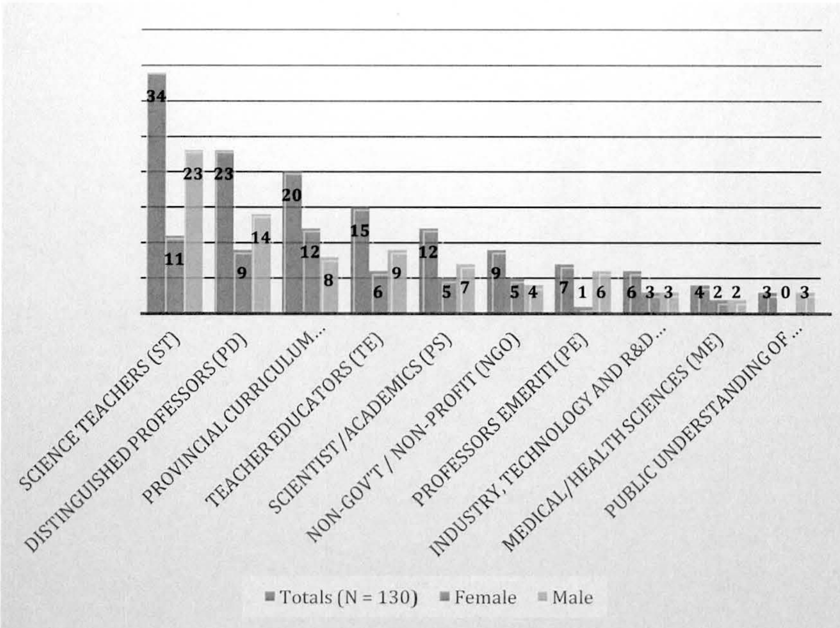
No emphasis was placed on having balanced gender among the candidate participants as it was professional orientation and current position as outlined above which determined the list of candidates. In total, 52 female and 78 male individuals were contacted directly to participate in the study.3 Figure 2 below provides a breakdown of the demographic in terms of gender and associated professional distinctions and Figure 3 identifies the professional affiliations and gender among the candidates:

Figure 2. Invited Candidates by Professional Distinction and Gender.



[3] The gender imbalance in the purposeful sample was the result of position, occupation, or in accordance with satisfying the selection criteria.

Figure 3. Invited Candidates by Profession and Gender.



For the purposes of geographic distribution among the invited candidates, the researcher's familiarity with the science education milieu in Manitoba is reflected in the oversampling in that jurisdiction. Alternatively, since the study was to be undertaken exclusively in English, early reconnaissance of the Québec science education environment demonstrated that there would be some difficulty in unilingual, second-language participation among individuals in Québec institutions. Figures 4 and 5 below outline the geographic distribution and gender mix of the expert panel invited candidates:

Figure 4. Invited Candidates by Jurisdiction

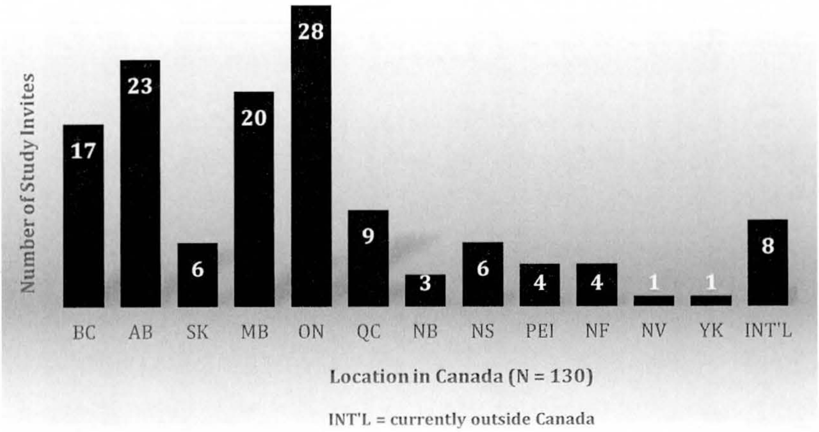
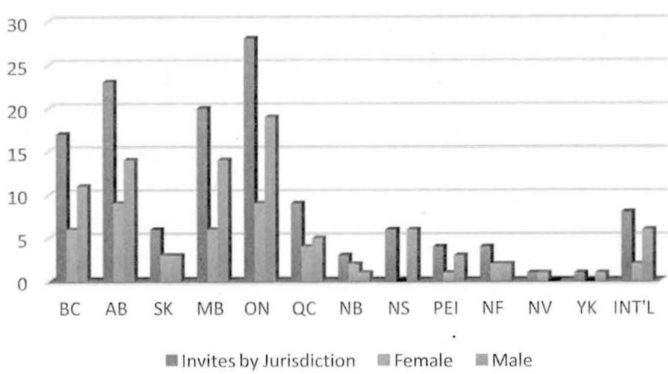


Figure 5. Invited Candidates by Jurisdiction and Gender



As stated earlier, the Delphi research method is useful in instances where the researcher seeks the exposure of expert opinion that is often generated in the form of initial dissensus, tension and conflict. Consensus positions, if these arise at all, are intended to occur naturally over the course of deliberations among the expert panel. The technique seeks a variety of policy alternatives on an issue and the available evidence supporting them rather than a group consensus as the primary objective. There is structured flow of information provided to the expert panel that includes a series of surveys, and reciprocal feedback to the group allows the panel to deal with a complex problem without the expectation of a binding set of resolutions as a final outcome. The anonymity of the process while it is underway is crucial to the technique's success. According to Linstone and Turoff (2002; [1975]), the following areas (and their associated research questions) suggest that a Delphi approach is appropriate on occasions where:

- "The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis;
- Individuals needed to contribute to the examination of a broad or complex problem, have no history of productive or adequate communication, and may represent diverse backgrounds or positions with respect to their experience or expertise;
- More individuals are needed than can effectively interact in a face-to-face exchange;
- Time, geography, and cost make frequent group meetings infeasible;
- The efficiency of any face-to-face exchanges can be increased by a supplemental group communication process;
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured, and;
- The heterogeneity of the participants must be preserved to assure validity of the results (i.e., avoidance of domination by quantity or strength of personality, and "bandwagon" effects."

In his The Wisdom of Crowds, James Surowiecki (2004) sought answers to how a collective of individuals – all having different experiences, wisdom, access to information, and experiences – can come together and create intelligent solutions to complex problems. He defined a "crowd" as "a group of people who can act collectively to make decisions and solve problems". In addition, Surowiecki was intrigued by groups that "were not really aware of themselves as belonging to a group". Important similarities exist in this anonymous "crowd wisdom" and the characteristics of the Delphi approach developed for this study. The current situation argued favorably for a technique well regarded in social sciences research and one which would provide candid input and deliberation. Surowiecki describes the circumstances well:

> "It needs to be diverse, so that people are bringing different pieces of information to the table. It needs to be decentralized, so that no one at the top is dictating the crowd's answer. It needs a way of summarizing people's opinions into one collective verdict. And the people in the crowd need to be independent, so that they pay attention mostly to their own information, and not worrying about what everyone around them thinks."

What was just stated could easily be a description of the ideal characteristics of any situation that mirrors the techniques and applications of the Delphi – diversity of opinion, independence, the creation of summaries of options, and anonymity.

Many would likely point out that this study relied upon the subjective judgments of an assembled expert community in the fields of Canadian science education and in allied fields holding specific interests related to education in the sciences. As such, the selected members for participation were located throughout Canada with some currently working internationally while maintaining strong research ties to Canadian associations or institutions. Some selected members participating in the study were no longer professionally active in the respective fields which built their reputations as experts per se, but nonetheless provided important historical perspectives. These individuals were especially important contributors in areas that focus on the key moments in the last 40 years of Canadian science education and the degrees of impact or effects that such periods had on the system of science education. A point, then, could be raised about how the study provided an effective demarcation between knowledge versus opinion. In order to address this concern, we need to make an appeal to the dialogues of Plato.

Knowledge, Opinion, and Knowledgeable Opinion in a Delphi Study

In Plato's famous dialogue, the Meno, we have the statement of a paradox which could be distilled to two simple questions: (1) How will you know what you are looking for if you first don't already know it (and thus have no reason to go looking for it)?, and; (2) "But why look for something you already have?". These positions were created by virtue of Plato's view of the immortality of the ψυχή (pneuma, or soul). That is, prior to the shock of being born we had a pre-existence within the realm of "Forms" which provided the basis for human understanding. It was also the basis for determining what was intelligible (Plato, 380 BCE; 2009). The act of birth erases all of this understanding of forms and we are then placed on a path (hopefully) of continuing to have experiences and the answers to the right questions such that we can recover the understanding (knowledge) which had been lost and is due to us. Epistemologically, Plato as rationalist differentiated knowledge from opinion with the former being superior and essentially residing within us and in essence, infallible. Opinion, on the other hand, was within the realm of sense perception, hearsay, opinion making and could not necessarily be trusted as being authentic or true and was most certainly fallible. There is not sufficient opportunity here to pursue the nature of scientific 'knowledge' on Platonic terms if it is indeed derived from falsifiable first principles (read Lakatos here). What we can do, however, is grudgingly accept some modification of Plato's strict demarcation with respect to knowledge and opinion and credit experienced science educators with having spent some time beyond the shadows cast on the prisoners of sensory experience by the puppeteers in the cave of the Meno. As summed up by Winchester (2006):

> "[for] the only reality is the reality shaped by our thought and actions, individually or collectively, or both. That is to say, essentially the world is a world which is produced by our imagination, not one simply found in nature" (op. cit.,p. 16).

To apply the above argument to the concern which could be raised about a Delphi study or, for that matter any study reliant upon soliciting expert opinion on large-context problems of interest, one needs to give consideration to what is acceptable as knowledge and what is expected as being opinion. Perhaps the two should be reconciled as knowledgeable opinion for our purposes of justification. Returning to the Meno argument we can state somewhat confidently that what is unchanging in the principles (or "Forms") among the members of this expert panel is their induction into the sciences and science education, and it is upon these fragile bases that one intends to be called an expert in the first place. In my view, if we can show that an opinion or belief contributed to the study is based on these shared principles grounded in the criteria of selection and face validity, we have a reasonably firm foundation for the opinions offered. That foundation is what allows us to think of a belief as more than simply opinion; it is what allows us to identify the belief that person holds, and that is what can be translated into knowledge for the purposes of the study. That knowledge, however, will not have the Platonic infallibility which is the ideal. Should it then be condemned as hearsay, mere opinion, imagination, and grotesquely fallible? Therefore, I suggest here that there is confidence that members of an expert panel can confess to, or self-identify with, having knowledgeability. Acting in combination with a group forecasting environment such as a Delphi, one can be equally satisfied that – within negotiated limits – the members of an expert panel can be sought out, selected, and bring forth guidance from knowledgeable opinion.

A second illustration of knowledge versus opinion can include the differences among: 1) knowledge deemed to come only through sense perception (cf. Plato's arguments in the Meno); 2) knowledge as informed judgement, and; 3) knowledge as true judgement which may be real because it is also attended by an account from the source (i.e., a rationale or justification). These three come to us in another Platonic dialogue – the Θεαίτητος (Chappell, 2013). In the Theætetus we observe a dialogue between the masterful epistemologist (Socrates) and a young man, Theætetus, both of whom are attempting to draw out from one another the nature of knowledge based on the three differences just outlined. Late in the dialogue, Theætetus seems to recall being told that true judgement with an account (the logos, or written justification) is sufficient to declare that we have knowledge which is trustworthy. Alternatively, things which lack an account can only be hearsay and are not knowable with any certainty. Unlike the Meno, wherein there seems to be some sort of resolution about the issue of knowledge versus opinion, in the Theætetus there is an abrupt end to the dialogue as Socrates hurries away to face his accuser, Meletus, in a court proceeding and so dismisses his young student with a whim that all definitions of knowledge are, in the end, unsatisfactory.

To perhaps now illustrate with a contemporary example from the literature, Holdaway, Deblois and Winchester (1994;1995) conducted a three-phase study of over 700 graduate student supervisors from an initial pool of 1,100 in 37 universities across Canada in order to access opinions, assess practices, and determine influential issues. It is not known by me if the particular study methodology used was eventually replicated as phase three elsewhere to include comparison studies in Australia, Great Britain, and other countries. Existing studies originating from the comparison countries may well have informed the earlier phases of the work from 1991 to 1993. The first phase of their work was specifically a Canadian study conducted among Canadian university graduate programs and inviting Canadian faculty as participants in the study. In that phase one study, Holdaway, Deblois & Winchester (1994) sought opinions from what they called "experienced supervisors" making use of the following: a draft pilot-phase questionnaire, free response items, numerical/descriptive scales, literature cited, interviews, commentaries, and analyses of responses into categorizations (in their instance these were disciplines and in my study these were themes for science education). Descriptive statistics were used in the analyses and inferential statistics were not used because the "experienced supervisors who responded were not a representative sample of all Canadian graduate supervisors" (p. 9). Differences in opinion which were considered "substantial" on the numerical/descriptive scales were assigned an arbitrary value of being ≤ 0.30 from mean values. Real differences in attitudes and opinions were identified simply as "gross differences in percentages of agreement". Every parameter just listed in the methodology of Holdaway, Deblois & Winchester (1995) in the follow-up article shares an almost mirror image to the techniques and decisions about demarcations defined in this study.

In order to determine more solidly a sort of first-order level of appropriateness for using Delphi in this study, it was important to determine if there existed in the literature an example of a Delphi study which shared strong connections to the design of this study and also had sufficient peer support as measured by citation counts or one appearing in a publication with the necessary impact index. As it would turn out, one of the best known Delphi studies of the last decade in science education was related to establishing priority areas for the nature of science in future curricula in the U.K. This was the Delphi of Osborne, Collins, Ratcliffe, Millar and Duschl (2003). It was originally published two years earlier with Collins as the lead author as a manuscript delivered at the 2001 conference of the American Educational Research Association (AERA) (Collins et al., 2001). To date, it is certainly the leading science education Delphi study in terms of science education research community impact factors (i.e., it is the most widely cited, with > 400 direct citations as of August, 2013, with more than 150 other Delphi studies among these citations). There seems to be sufficient levels of literature support for the technique used here.

Data Collection and Analysis

The study was implemented over a 17-week period early in 2014 with the final panel of experts differentiated across two distinct cohorts demarcated by the era in which the majority of their contributions were made professionally. COHORT 1 began their professional careers in the early 1990s while COHORT 2 members had experience which spanned the decades of the 1960s, the 1970s, the 1980s and forward. Hence, one group is approaching or is at mid-career and the other is late-career into retirement age. The sample description and methodology section earlier in this paper outlined these distinctions more fully. The Delphi began with an initial round where all members of the expert panel (N = 54) were asked to respond at length to four open-ended "seed questions" in Round 1. These 'seed questions' were as follows:

- 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.
- Question 3: The Canadian provinces and territories have constitutional guarantees providing them with exclusive responsibility for education.....Given this federal system, what (if any) opportunities and barriers exist for the development of a new national vision for science education in Canada? For any opportunities and/or barriers you have identified, what procedure(s) and/or changes to the current system as you see it do you recommend in making such a national vision a reality for Canadians?
- Question 4: In your view, should there be a uniquely Canadian approach to science education in our system of education? If so, what (if any) would be its most visible, distinguishing characteristics as viewed by the people of Canada and the international community? If no, why is this not possible or desirable for science education? In your response, please give as clear a description and justification of each idea you present as is possible.

The total range of response length to each of the four 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. Once all the respondents' data was in, it was the responsibility of the researcher to then exhaustively code the data using techniques in common use in qualitative research. The purpose of the coding was to determine the principal themes arising in the data, and one of the first practices was to construct "word frequency" analyses. This type of analysis, utilizing NVivo 10™ Computer Assisted Qualitative Data Analysis Software (CAQDAS) allows for keywords to emerge from the data which then are used in the coding of the text. In essence, the research model "asked" the data to provide the important ideas which is an important safeguard against too much steering of the research by the investigator who otherwise could become quite embedded in the Delphi.

In all, some 47 nodes, or themes, emerged from Round 1 of the Delphi across five broad macro-scale node categories organizing science education in Canada. What follows is a listing of those macro-scale nodes and their subordinate nodes:

a. Global Trends Affecting Science Education to 2030 (11 nodes)
   I. Science, Technology, Engineering & Mathematics (STEM)
   II. Integration of Indigenous Perspectives / Knowledge
   III. Developing Skills for the 21st Century
   IV. Science and Education for Sustainability
   V. National/International Student Assessments (e.g., PISA, TIMMS, PCAP)
   VI. New Learning Technologies
   VII. Relevance of Science Education to Students
   VIII. National / International Standards
   IX. Science Education for Economic Competitiveness
   X. Re-conceptualizing the Purposes of Science Education
   XI. Globalization of the International Community and Neo-Liberal Values

b. The Foundations of Canadian Science Curriculum to 2030 (7 nodes)
   I. Science Education for Global Citizenship
   II. Science Education for Sustainability
   III. The Nature of Science
   IV. Science, Technology, Society and the Environment (STSE)
   V. Interacting Systems and Systems Thinking
   VI. Scientific Skills for the 21st Century
   VII. Scientific Knowledge

c. The Goals of Canadian Science Education to 2030 (11 nodes)
   I. Democratic Citizenship in a Global Technological Society
   II. Career-building for a Technological Society
   III. Economic Competitiveness
   IV. Literacy in Science-Related Issues
   V. Personal Character Development
   VI. Life-Long Learning
   VII. Contribute to Human Health and Well-Being
   VIII. Training of Future Scientists
   IX. Develop a Deep Sense of Wonder and Curiosity
   X. Pursue Progressively Higher Levels of Study
   XI. Sustaining Earth's Systems

d. Opportunities and Barriers to a National Vision for Science Education to 2030 (7 nodes)
   I. Voices of Indigenous Peoples
   II. Cultural Diversity
   III. Linguistic Diversity
   IV. Provincial Electoral Cycles
   V. Federal Electoral Cycles
   VI. Control of Curriculum by Provincial Ministries of Education
   VII. Physical Geography

e. A Canadian Approach to Science Education to 2030 (11 nodes)
   I. Canada as a Circumpolar Nation
   II. Indigenous Ways of Knowing
   III. Issues of Gender
   IV. Issues of Human Rights
   V. Regional Priorities
   VI. Relationships with Trading Partners
   VII. International Student Collaborations
   VIII. Science Education for a Democratic Society
   IX. Career Specializations in the Sciences
   X. Equity of Opportunity in the Sciences
   XI. Science Education for a Sustainable Future

Following Round 1, the expert panel then went about the task of giving priority status to each of these themes through a rating exercise. Round 2 provided the expert panel with an opportunity to rank each of these 47 themes and provide written justification for their position. If one looks at the five macro-scale nodes which emerged from expert panel opinion-making, a rather comprehensive description of the science education experience in Canadian schools has been constructed. Whether it be curriculum policy, re-imagining the purposes of science education, identifying barriers and opportunities for change, or the development of a uniquely Canadian approach to science education, the panel had something to say on a multitude of fronts. The difficulty then rests with determining which of these should constitute areas of focus in Canadian jurisdictions.

Global Trends Affecting the Future of Science Education to 2030

The list below summarizes those trends, issues, and areas of focus that the expert panel determined as being the most influential in shaping new visions of science education in Canada (followed by some selected and representative commentary from study participants):

- Globalization Influences
- Skills for the 21st Century
- Science Education and Sustainability
- Emergence of New Technologies for Learning
- The Relevance of Science Education for Students, and
- Science, Technology, Engineering and Mathematics (STEM)

> "Globally there is a push to assess the developmental level among students of broad skills, often referred to as '21st century skills'. There is a lack of clarity about how these skills are defined, how they can be discussed, how this looks in classrooms, and how these 'skills' should be assessed. It's hard to tell if this is a fad or if a transition to skills will underpin curriculum reform. Several provinces have consulted on education curriculum reform and all are talking about these skills, but are defining them slightly differently and / or calling them 'competencies' "

> "It should not be surprising that the science of sustainability is of essence to be integrated into other disciplines. On what alternate grounds would the future of science education rest? Concerns about sustainability, health, energy, and water are examples of significant issues that face today's societies and involve government policies and action. These issues are interconnected to science and technology. School science courses are typically organized around traditional disciplines of science, yet these are artificial in today's world. Science-related fields such as biotechnology, energy, environmental sciences, climate change sciences and agricultural sciences are interdisciplinary across multiply-connected areas of science as well as holding consideration for technology and its societal impacts. Furthermore, science itself is involving a greater degree of collaboration and cooperation among countries to address these multi-faceted issues. These socio-scientific issues require understanding more than the underlying science concepts; they involve making decisions about science and technology issues."

Round 3 of the Delphi provided a second opportunity to re-visit each of these themes after considering the opinions of their fellow participants which emerged from the previous round. At this point, the researcher looks for stability in respondents' positions, movement in position, or instances of broad agreement or disagreement. At the end of Round 3, there were 42 members of the expert panel contributing of the original 54. What follows is what the expert panel came to consensus on as to the big issues and trends which will likely influence the future course of science education in Canada:

Table 1: Perceived influence of most desirable global trends influencing science education in Canada

COHORT 1 (N = 21)	COHORT 2 (N = 21)
Science and Education for Sustainability**	Science and Education for Sustainability
Development of Science Inquiry Skills	Relevance of Science Education for Students
Relevance of Science Education for Students	Development of Science Inquiry Skills
Re-Conceptualizing the Purposes of Science Education	Science, Mathematics, Engineering & Technology (STEM)
New Learning Technologies	New Learning Technologies

HIGH Influence → LOWER Influence

* Decreasing order of desired influence on science education in Canada
** 100.00% consensus level

Table 2: Perceived influence of least desirable global trends influencing science education in Canada

COHORT 1	COHORT 2
National / International Student Assessments (e.g., PISA, PCAP, TIMMS)	Integration of Indigenous Perspectives **
National / International Standards	Re-Conceptualizing the Purposes of Science Education **
Integration of Indigenous Perspectives **	National / International Student Assessments (e.g., PISA, PCAP, TIMMS)
Science Education for Economic Competitiveness	Relevance of Science Education for Students
Science, Mathematics, Engineering & Technology (STEM) **	Science Education for Economic Competitiveness **

HIGH Opposition → LESS Opposition

* Decreasing order of opposition to their influence on science education
** High variance in responses ($\sigma \geq 1.00$)

"The involvement of Indigenous peoples in science education is paramount. Indigenous philosophies, ontologies, methodologies and pedagogical practices need to be part of the development of science education frameworks. This is essential if we are to foster greater Aboriginal student engagement in the sciences…learners

> who often have to engage in "border crossing" in order to 'feel' the science. In Canada, there is a critical underrepresentation of Aboriginal people going into science-related programs at the post-secondary level. This has an impact on their ability to participate fully and representatively in the world's scientific communities on an equitable footing."

The foundations and goals of Science Education in Canada to 2030

The free-form Question 2 in the questionnaire instrument offered the members of the expert panel an opportunity to project their thinking forward and provide personal and professional insights into what they believed would be the important foundations and goals of science education in Canada to 2030. For the purposes of this study, "foundations" can be viewed as the "big ideas" which should underpin why we have science education in Canadian schools. Often, such foundations form the basic architecture of curriculum development. The largest proportions in terms of textual references based on reflexive and iterative coding included the following in the category of "foundations":

- Science, Technology, Society and the Environment (STSE)
- Science Education for Sustainability
- Scientific Knowledge
- Science Education for Global Citizenship
- Scientific Skills for the 21st Century
- Interacting Systems and Systems Thinking
- Understanding the Nature of Science

Table 3: Foundations for science education in Canada

COHORT 1	COHORT 2	
Science and Education for Sustainability**	Science and Education for Sustainability	HIGH Importance
Science, Technology, Society and Environment (STSE) **	Science, Technology, Society and Environment (STSE)	
Scientific Inquiry Skills	Scientific Inquiry Skills	
The Nature of Science	Science Conceptual Knowledge	
Science Conceptual Knowledge	The Nature of Science	LOWER Importance

* Decreasing order of desired importance as foundations for curriculum development
** ≥ 95.00 % consensus level

> "Training scientists and preparing students to continue their education is important, but this should not be the role of science education. We should not teach to a small percentage of students only; thus, the higher and broader goals of preparing citizens for a globalized society, taking into consideration sustainability issues, is much more important, in my opinion."

When we consider the goals of science education, the expert panel concentrated in identifying and describing what should be the desired results of the K-12 science education experiences of Canadians. In total, there were five goals which emerged as priority consensus areas for science education. In decreasing order of importance, these include:

- Literacy in Science-Related Issues
- Contributing to Human Health and Well-Being
- Developing a Deep Sense of Wonder and Curiosity
- Sustaining Earth's Systems
- Citizenship in an Interconnected Global Technological Society

Table 4: The goals for science education in Canada

COHORT 1	COHORT 2	
Literacy in Socio-scientific Issues**	Literacy in Socio-scientific Issues**	HIGH
Contribute to Human Health and Well-Being	Contribute to Human Health and Well-Being	
Life-long Learning	Citizenship in a Global Technology-Rich Society	
Citizenship in a Global Technology-Rich Society	Life-long Learning	
Building Careers for a Technological Society	Building Careers for a Technological Society	
Economic Competitiveness	Economic Competitiveness	LOW

* Decreasing order of desired importance for the learner and the orientation of learning experiences
** 100.00% consensus level

"Although I understand the importance of economic competitiveness and career-building, I am not supportive of these as driving goals for science education. I do think that career awareness is very important so that students are aware of the myriad careers that related to STEM, but I worry if students are given messages that they must focus on careers and their place in the economy whether they are still formulating their interests and learning about the interconnectedness of world human and natural systems."

"I think we as a country have started to erode the importance of science education. We have focused so intensely on literacy and numeracy that other subject areas have become to suffer. When I look at the state of many labs in our schools, I see evidence of this neglect. I am reminded of the Demon-Haunted World of astronomer Carl Sagan. He pointed out the effects of that a lack of interest in science and science education can have on a society. We have set up a society so dependent on science and technology that few people really understand its deeper, inner workings. If science and technology have so much impact, who stands to make the decisions about its use and future? With this mix of dependence and lack of understanding of science and technology we create a situation that will possibly be limiting. We may well create an environment of misunderstanding, indifference, and "a new darkness". Out of the darkness come the mystics and soothsayers. To grab for better understanding, pseudo-science becomes an easy to understand alternative. Who then are making the decisions for our future? It must be the science literati of society that makes these decisions."

"I am responding to this question knowing what the Intergovernmental Panel on Climate Change is predicting for 2025 and beyond. From my perspective, science education must be education for sustainability and science education for sustainability incorporates: (a) developing student understanding of natural systems, human systems, human global systems and the interactions of these systems, (b) developing student understanding of the relationship of science and technology, the impact of society on science and technology and the environment, and the impact of science and technological innovations on society and on the environment, (c) developing student understanding of the nature of science (why scientists do what they do and believe what they believe), and (d) developing student understanding of scientific knowledge."

Opportunities and Barriers to a new vision for Science Education in Canada to 2030

The thinking among expert panel members on issues of the degree to which Canada's federal system is responsive to educational and curriculum change was quite varied and at times polarized but respectful. Participants have identified an array of contexts that are considered to be of influence in defining the future landscape of Canadian science curriculum, and some of these are contested, including: the nature of Canadian communities and cultural diversity; First Nations / Métis / Inuit (FNMI) perspectives; the possibility of national standards becoming a reality (e.g., STEM); the legacy of the Pan-Canadian Science Project of the 1990s, and perhaps most importantly the critical and visible role of the Council of Ministers of Education Canada (the CMEC). On the role of the CMEC, the expert panel held a greater than 78% consensus that the CMEC should begin the process of securing a new national vision for science education in Canada – not a new national curriculum framework, however, but a leadership from a visionary position.

The present mobility of the Canadian population, alongside regional adjustments to demographics due to the dynamic of immigration factors is seen as a contributor to the context of any discussions about a national vision for science education in Canada. That is, the complexion of Canadian communities is undergoing rapid change. This raises questions as to how best to serve the new Canadian and international dynamic. Canada was observed to be defined, in part, by its vast geography and circumpolar position and these defining characteristics could affect and provide shape to the kind of science education envisioned by the expert panel. First Nations, Métis and Inuit (FNMI) perspectives on the systems of the planet 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.

Table 5: Threats and opportunities confronting a Canadian consensus on science education

Threat Level	Opportunity Level	
Provincial Electoral Cycles	Inter-Provincial Cooperation	HIGH
Control of Curriculum by Provincial Ministries	FNMI Voices and Perspectives	
Federal Electoral Cycles	Cultural and Linguistic Diversity	
National/International Science Assessments	Landscape, Physical Geography, Circumpolarity	
Science Education for Int'l Competitiveness	Council of Ministers for Education (CMEC)	LOW

> "I now view that jurisdictional responsibility for education is a strength and an opportunity – not an obstacle to change. This does not mean that this system is not without its challenges, but I firmly believe that the "cultures" within jurisdictions are best reflected by jurisdictional responsibility for K-12 education where schools are part of local communities in that place. I also believe that within our Canadian education systems – note I use a plurality here - that a mechanism is needed for collaboration and cooperation. The Council of Ministers of Education, Canada is a forum that provides this. Established in 1967, this intergovernmental body was created to allow for Ministers of Education (and its executive advisory panel of deputy ministers) to meet and discuss policy issues."

> "Although I am supportive that the CMEC can provide an effective mechanism to provide national direction, I do not believe that the role of CMEC is well understood by educators, let alone the public and other stakeholders interested in K-12 education. The CMEC needs to communicate more effectively what its role is and having the public (including educators) understand that there is a forum where national direction can be discussed and set. However, there has to be political will within the jurisdictions that science education is important enough for discussion."

Consensus on who should provide guidance to science education

There is perhaps no other issue that invites contested commentary in education more than "who has the mandate to design, construct, and implement the curriculum?" That question is fully settled at a practical level by virtue of the legitimate authority invested in the Canadian provinces and territories who exercise a constitutional imperative in education. Outside of the 'practical', such a question is not so easily settled among those who also have a constitutional entitlement to an opinion. As one member of the expert panel put it:

> "Teachers are of course crucial but the reality is that they are immersed in the current paradigm and really don't have the time to study the long view. People who study pedagogy ought to take the leadership role, as they may take the

long view. With the ever present tensions between government and teachers, I would put the civil servants and the teachers side-by-side under the neutral third party- the education faculty."

In both Round 2 and Round 3, the expert panel was requested to provide a rating across multiple stakeholders as to what their role should be in the actual curriculum development process. The question was very precise, and it is worth noting how it was presented to the panel:

In your opinion, please rate each of the stakeholder groups listed here as to what you believe their appropriate level of contribution should be to the actual development of Provincial science curriculum in Canada. Where 5 = Leadership Role (can make final decisions), 4 = Collaborative Role (working directly with leadership with some decision-making), 3 = Advisory Role (providing information and some direction to the process), 2 = Observer Role (can access the process; no input), 1 = No Role (no influence on the process).

Presently, most of the Canadian provinces exercise some form of multi-stakeholder involvement, but this can be highly variable and change over time in response to political influences. In Round 2 of the Delphi, the expert panel provided opinion on roles and responsibilities across ten stakeholder groups:

- Ministers of Education in the Canadian Provinces
- Senior staff in provincial ministries of education
- Science education specialists in ministries of education
- Industry professionals (e.g., R&D)
- Faculties of education at Canadian universities
- Faculty and instructors at Canadian colleges of applied arts and technology
- Parents of K-12 students
- K-12 students
- Science teachers at K-12
- Academic scientists

In Delphi Round 3, in response to a number of requests by members of the panel to enlarge the list, six more were added to bring the total to 16 stakeholders which then included these new roles:

- Aboriginal Elders and Knowledge-Keepers
- Concerned citizens (claiming to be conflict-free)
- Scientists not in academia
- Science communicators (e.g., media, writers, outreach)
- Labour organisations
- A Provincial/Territorial roundtable with representation from the all other groups.

Once the expert panel had deliberated on the influences of stakeholder groups, a consensus emerged that just three groups should have ultimate (and balanced) signing authority in matters of science curriculum development including final decision-making on curriculum frameworks. These three participant groups are:

- K-12 Science Teachers (with exemplary credentials; > 90% consensus)
- Faculty in Programs of Education (both Colleges and Universities; >78% consensus)
- Science Education Specialists in Ministries of Education (visibly led by the Minister; > 74%)

The following chart summarizes the key findings with respect to the question, "Who should be responsible for designing the science curriculum in Canada?

Decision-Makers	Advisory Roles	No Defined Role
K-12 Science Teachers	College Faculty	Labour Organisations
Faculties of Education and Teacher-Educators	Aboriginal Elders and Knowledge Keepers	Concerned Citizens
Science Education Specialists in Ministries of Education	Academic Scientists	Parents of K-12 Students
	Industry Professionals	Science Media / Writers
	Ministers of Education	K-12 Students
	Senior Staff in Ministries of Education	Industry Scientists

CONSENSUS POSITIONS FOR SCIENCE EDUCATION IN CANADA TO 2030

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 when compared to recent visions for science education in other nations. The expert panel has positioned many of its priorities in such a way as to not necessarily be in alignment with certain other major developments in the OECD countries. Three examples of this would include: (1) STEM education and low levels of interest in the adoption of the recently-released Next Generation Science Standards in the United States (National Research Council, 2012; Achieve Incorporated, 2013); (2) Economic competitiveness internationally as a significant driver of the purposes of science education in Canada, and; (3) The role of national and international assessments (e.g., PCAP, PISA) in shaping the priorities for science education in Canada. These, and other factors, are likely to continue to generate tensions within the science education community for the foreseeable future. The following consensus positions have been identified from the Delphi forecasting of the expert panel (at the $\geq$ 70% level or greater):

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 Skills for the 21st Century, 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 to 2030, 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; and,

E. A desire for more inter-jurisdictional cooperation in science education within the constraints of provincial electoral cycles and jurisdictional control of education systems in Canada.

The Sustainability Sciences – A New Paradigm for Science Education in Canada?

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" view) with the planet's environmental limits as a set of networked systems operating on the time scale of geology (the "biocentric" view). Sustainability science is not environmental science. Sustainability science recognizes that conducting any science outside of an environmental context is not remotely conceivable nor is it appropriate. As Clark & Dickson (2003) 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 (NRC, 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."

The expert panel provided perspectives on the necessity, value, and expedient with respect to the sustainability sciences. So much so that it was simultaneously considered as: (a) expected to be and desired to be a "defining influence" as a future trend impacting science education; (b) a new foundation area for science education; (c) literacy in science-related issues, human health and well-being, and sustaining Earth's systems were identified as new 'goals' for science education, and; (d) science education for a sustainable future was characterized by > 90% of the expert panel as what would be among uniquely Canadian contributions to international science education to 2030. This new aspect for science education in Canada has now clearly been granted the credibility and status required to take action. The Delphi expert 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. This new terminology can now be introduced – Sustainability Science, Technology, Economy and Environment (SSTEE) which is presented here as the principal, guiding foundation for science education in Canada. The term provides historical continuity to the Science, Technology, Society and the Environment (STSE) movement which was a uniquely Canadian contribution to science education internationally and has been at the foundation of curricula in Canada for three decades.

Recommendations for Change from the Expert Panel

At the outset, this study sought to resolve this core research question, which can be framed as follows:

According to the perceptions of an assembled 'expert community' of science educators and those with deep interests in science education, what are the principal theoretical *foundations, guiding assumptions, and purposes for the future of Canadian science education which can be forecasted?*

In conclusion, the Delphi panel of experts provides the following recommendations should provide impetus for further research, deliberative conferences, curriculum re-visioning and reconstruction, and actions among Canadian ministries of education and their educational partners:

Recommendation 1

- That the Council of Ministers of Education, Canada, in collaboration with its advisory committee of Deputy Ministers of education, initiate national-level consultations to deliberate on a new vision for science education in Canada to 2030.

Recommendation 2

- The findings of the study provide the basis for, contribute substantially to, and constitute a potentially new challenge to, the status quo in science education in Canada. The expert panel consensus has presented a strong argument for commissioning a new phase of national discussions on the very purposes of science education with in the Provinces;

Recommendation 3

- Together with its Provincial/Territorial partners, the panel encourages emergent commitments to a new vision for 21st century science education in Canada grounded in the foundation area of the "sustainability sciences".

Recommendation 4

- Encourage and strengthen the roles and responsibilities of the stakeholders in science education in recognizing the unique circumpolar position of Canada's geography with particular reference to its indigenous peoples and their unique relationship to knowledge-keeping, to the landscape, and to fundamentally non-Eurocentric traditions which guide their "border crossing" into the sciences.

Recommendation 5

- Establish new science education research traditions in 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 Skills for the 21st Century, the Relevance of Science Education for Students, and Re-Conceptualizing the Purposes of Science Education.

Recommendation 6

- That new terminology – Sustainability Science, Technology, Economy and Environment (SSTEE) enter the discourse in science education and be identified as a principal, guiding foundation for science education in Canada; further, it is recommended that this new term provides historical continuity to the STSE movement which was (and remains) a uniquely Canadian contribution to science education internationally.

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