

THE LOGIC OF CONSENSUS ON THE FOUNDATIONS OF SCIENCE

EDUCATION IN CANADA:

A DELPHI STUDY

by

JOHN JAMES MURRAY

A Thesis submitted to the Faculty of Graduate Studies of
The University of Manitoba
in partial fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

Faculty of Education
University of Manitoba
Winnipeg

Copyright © 2014
JOHN JAMES MURRAY

Abstract

Despite episodes of particularly 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 contested, it will be argued here and supported by the research that the Canadian systems of science education operating in the provinces and territories have not had opportunity, historically, to engage in curriculum uniquely from Canada 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 this dissertation was to empirically determine, and provide definition to, the principal theoretical foundations and system conditions for a Canadian approach to science education. The study included the following sub-objectives:

1. Define and describe system conditions that will initiate and influence future development of science curriculum in Canada.
2. Determine and describe the theoretical foundations, goals, and objectives for the science curriculum in Canada.
3. The characterization and establishment of a logic of consensus on a Canadian approach to science education.

The research was conducted and documented through an online, anonymous, and asynchronous modified policy Delphi methodology. The form of policy Delphi adopted in this study is a variant of the classical Delphi group forecasting method which anticipates both consensus and dissensus positions. Over a four-month period, an assembled expert panel of 54 peer-acknowledged and representative science education specialists from Canada - comprising fourteen identifiable professional affiliations in two cohorts - participated in a Delphi having three rounds.

Guided by the research questions, the findings from this first-of-kind Delphi among leading Canadian science education specialists has identified the following positions deemed as consensus:

- 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;
- 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;
- New terminology – Sustainability Science, Technology, Economy and Environment (SSTEE) is presented as a principal, guiding foundation for science education in Canada; the term provides historical continuity to the STSE movement which was a uniquely Canadian contribution to science education internationally and stands in opposition to the current trend of Science, Technology, Engineering and Mathematics (STEM);
- 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;
- 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; addressing the problematic situation of Canada's indigenous peoples as underrepresented in the post-secondary and professional pathways of the sciences, and; the desire for more inter-jurisdictional cooperation in science education within the constraints of provincial electoral cycles and constitutional control of education systems in Canada.

In addition, the study has identified certain areas of interest and opinion-making which can be considered as dissensus positions which identify often polar disagreement among panel members. Certain of these constitute contested areas of innovation wherein the science education discourse is yet to establish strong theoretical bases for their treatment and incorporation into curriculum frameworks. The following contested areas emerged in the Delphi:

- The integration of First Nations', Métis, and Inuit perspectives as contributors to a third vision of science education which complements the Vision I and II science of Roberts (2007;2011);
- The re-conceptualisation of the foundations of science education in Canada;
- The future role of K-12 science education in terms of the development of the next generation of Canadian science specialists and its relationship to globalising influences centred on models of economic growth;
- The preferred role of academic scientists in the development of science curriculum in the Canadian provinces and territories.

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 across areas now considered constitutive of science education in Canada for the next generation presents a strong argument for commissioning a new phase of national discussions on the purposes of science education led by the Council of Ministers of Education, Canada. Together with its provincial and territorial partners, the panel supports and encourages the emergence of commitments to a new vision for science education in Canada grounded in the sustainability sciences.

Keywords: Canadian science education, curriculum, modified Delphi study, policy Delphi, science education.

Copyright © 2014
JOHN JAMES MURRAY

Acknowledgements

"In times of change, the learners inherit the earth, while the learned find themselves beautifully equipped to live in a world that no longer exists."

(Eric Hoffer)

I offer my sincere gratitude to my senior advisor, Professor Don Metz, of the University of Winnipeg and my doctoral committee members, Professor Emeritus Arthur Stinner, Dr. David Walker, and Professor Ralph T. Mason, all of the University of Manitoba. Each brought to this project a unique set of talents and perspectives, and I am particularly impressed with the amount of careful attention provided to me as the journey was undergoing unique turns.

To Dr. Christina McDonald, Professor Emeritus G. Gordon Robinson, Dr. Barbara McMillan, and Dr. Brian Lewthwaite for teaching me and helping me trod the pathways and networks of systems and sustainability. In endless hours of stimulating discussions, they reminded me that even scholarship rests upon the very systems of Planet Earth upon which we so critically depend. They are all exceptional and have a vision for science and education.

To Professor Ian S. Winchester of the Werklund School of Education, University of Calgary, for his generosity in acting as the External Examiner of the thesis. In his particular and characteristic scholarly and gentle manner, I was reminded that I am among the shadows in Plato's cave searching for meaning and the distinctions among wisdom, knowledge, and opinion.

To the members of the expert panel who assembled themselves online, not knowing each other's identities, but nevertheless offering unimaginably remarkable insights into the future of science education in Canada. They are the Oracles who breathed in the ineffable vapours of Delphi, and have offered to Canadians a new vision full of hope and unbounded aspirations to remake the planet's health through education. It remains for me to be the Pythia to their oracular pronouncements.

To Dr. Graham W. F. Orpwood and Monsieur Jean-Pascal Souque, founding partners of the Science Council of Canada study in Canadian science education, for many helpful discussions on deliberative inquiry, sound methodologies, and reminding me of the importance of having everyone give voice to a project when it involves Canadian thinking and values. They were the first to do it, and no one has done it better since their seminal work in the 1980's. I was honoured to follow their lead.

Dedications

*"We shall not cease from exploration, and the end of all our exploring will be to arrive
where we started, and know the place for the first time."*

-- T. S. Eliot

To my wife, Christina.....

...for whom all that I have loved was but a remote preparation for loving her...with a depth and promise that only God can give....she has opened an entirely new flower of creation for me, and is my inspiration, my muse, my Oracle, and my joy....

To my family....

.....to my Mother and Father, James and Anne, my first teachers in all things that are possible, from throwing a baseball to singing the Psalms...to my sister Maureen and brothers David, Paul, and Timothy...and to those little ones, the children.....

Chad Alexander, Nicole Marie, Chelsea Christina, Tyler James, and Mikhaela Danielle, all of whom remain my sources of endless awe and wonder about what is possible as they grow. They constantly remind me of the value of being at play in the fields of the Lord....

To a special friend....

Gerry S. Smerchanski, without whose influences over many years (and many beers!) this project would have never been deemed possible or necessary...for he lives in a world where all hypotheses are tenable, paradigms abound, and he put my feet firmly on the perilous road to "multiple working hypotheses" ...*ad luna et ad astra*...

To my mentors....

...Art Stinner and Don Metz, who had the patience and the interest to set aside some time, to teach me that science has a remarkable history....; Eric MacPherson, who was a rare and challenging individual, and pays attention to the ineffable flapping of butterflies' wings...; and to Marie Collette and Rev. Joseph Hennessey, who instilled in me the desire to do well in all things; but above all, to read and write and Love in all things well...

.....and to KJH.....in fond remembrance of our many walks along the seashore of the Avalon among the enigmatic Cambrian rocks which hold the remnants of the first life on Earth.

Now, he knows....

Table of Contents

Abstract	ii
Acknowledgements vi	
Dedications viii	
List of Tables xiv	
List of Figures xv	
List of Appendices xvi	
Chapter 1: Introduction.....	2
A Summary of Positions and Introduction to the Study.....	2
Background of the Study	5
Set 1: Curriculum Policy as Values.....	6
Set 2: Curriculum Policy as Authority	6
Statement of the Problem and the Frame for Research Questions	9
The Purpose of the Study and the Research Questions	21
Primary Research Question (PRQ):	22
Ancillary Research Questions (RQn):.....	22
Significance of the Study	23
Theoretical Frame, Guiding Assumptions and Limitations of the Study	27
Contributions to Knowledge.....	33
Organization of the Study	35
Chapter 2: Literature Review I – Science Education in Canada.....	37
Science Education in Canada 1957 – Present: An Overview	37
Trajectories in Science Curriculum Development.....	39
Trajectory 1 - A Sense of Urgency: Post-Sputnik Era and Science Education in the National Interest	40
The Structure of the Science Disciplines	45

Trajectory 2 - Science, Technology, Society and Environment and the Re-Emergence of Science Literacy	49
Trajectory 3: Outcomes and Standards – the New Literacy of International Liberalism and Competitiveness	Neo- 57
The Pan-Canadian Protocol for Collaboration on School Curriculum.....	63
Chapter 3: Literature Review II – The Delphi Method	69
Delphi Methodology: The Conceptual Framework and Considerations for other Research Designs.....	69
The Delphi Method – History, Threats, and Opportunities.....	78
The Delphi Method Modified – Adaptation to Graduate Studies in Science Education.....	88
A Variant of the Delphi Method: Towards Policy Delphi and Issues of Curriculum.....	92
Appropriateness of the Policy Delphi Research Method to the Proposed Study	96
Knowledge, Opinion, and Knowledgeable Opinion in a Delphi Study	101
The Delphi Method: The Literature Informs the Sample Frame and Sample Plan	106
Chapter 4: The Methodology	111
Purpose of the Research.....	113
Development of the Research Questions	114
The Research Questions:	116
Primary Research Question (PRQ)	116
Ancillary Research Questions (RQ):.....	116
Choice of Expert Panel Members.....	116
Criteria for Inclusion on the Expert Panel.....	119
Selection Process to Establish the Expert Panel	122
Instrumentation and Procedures	133
Round 1 of the Delphi.....	133
Round 2 of the Delphi.....	140
Round 3 of the Delphi.....	147
Summary of the Methodology.....	156

Chapter 5: Data Collection and Analysis I	157
Expert Panel Participation Synopsis.....	158
Round 1 Data Analysis and Results	161
Word Frequency Analyses.....	161
Emergence of Themes in Round 1	177
Summarizing the Themes from Round 1	179
Assessing the Themes in Rounds 2 and 3 of the Delphi	236
Chapter 6: Data Collection and Analysis II	252
Primary Research Question (PRQ)	254
Ancillary Research Questions (RQx).....	254
Data Analysis of Delphi Round 1: Research Question RQ1	255
Data Analysis of Delphi Rounds 2 and 3: Research Question RQ1	268
Data Analysis of Delphi Round 1: Research Question RQ2	275
Data Analysis of Delphi Rounds 2 and 3: Research Question RQ2.....	277
Data Analysis of Delphi Round 1: Research Question RQ3	289
Data Analysis of Delphi Rounds 2 and 3: Research Question RQ3 Part I.....	292
Data Analysis of Delphi Rounds 1, 2 and 3: Research Question RQ3 Part II	307
Chapter 7: Summary, Discussion, and Recommendations	323
Summary of Findings by Research Questions.....	323
Research Question RQ1.....	325
Research Question RQ2.....	328
Research Question RQ3.....	332
Discussion and Recommendations.....	340
Methodological Contributions.....	342
Implications of the Research.....	344
Recommendations.....	350

References	357
Appendices	424
Appendix ‘A’	426
Letter of Invitation to the Study.....	426
Appendix ‘B’	429
Letter of Informed Consent to Participate in the Study.....	429
Informed Consent Form.....	431
Appendix ‘C’	439
Delphi Round 1 Questionnaire	439
Appendix ‘D’	446
Delphi Round 2 Questionnaire	446
Appendix ‘E’	466
Delphi Round 3 Questionnaire	466
Appendix ‘F’	496
Interview Questions Protocol	496

List of Tables

Table 1: Dissertations and Theses using the Delphi Method in Education, 1970 – 2019.....	107
Table 2: Dissertations and Theses in Science Education from Canadian Universities Using the Delphi Method, 2000 – 2013.....	109
Table 3: Sample Page of Round 2 Theme Summary for Expert Panel.....	166
Table 4: Expert Panel Participation Rates in the Delphi Study.....	176
Table 5: Theme Nodes Derived from Reflexive Coding of Round 1 Responses.....	189
Table 6: Theme Ratings for COHORTS 1 and 2 in Round 2.....	256
Table 7: Theme Ratings for COHORTS 1 and 2 in Round 3.....	262
Table 8: Combined ratings and consensus levels for RQ1 – Global Trends Affecting the Future of Science Education.....	287
Table 9: Combined ratings and consensus levels for RQ2 - the Foundations of Science Education.....	296
Table 10: Combined ratings and consensus levels for RQ2 – the Goals of Science Education.....	301
Table 11: Expert Panel Ratings to Policy-Making Positions in Science Education (COHORTS 1&2).....	315
Table 12: Expert Panel Ratings – Canadian Education Systems – Favourable to a New Vision for Science Education (COHORTS 1&2).....	316
Table 13: Expert Panel Ratings – Should the CMEC Initiate New Vision for Science Education? (COHORTS 1&2).....	317
Table 14: Expert Panel Ratings – Stakeholder Consultations in Science Education Policy-Making (COHORTS 1&2).....	318
Table 15: Expert Panel Ratings – Collaboration by Canadian Provinces on International Science Education Standards Development (COHORTS1&2).....	320
Table 16: Contributors to a National Vision for Science Education – Factors Unique to Canada.....	321
Table 17: Roles and Responsibilities in Canadian Science Curriculum Development.....	328
Table 18: The Relative Importance of the Core Objectives of a Canadian Science Education – in 1984 and Today.....	336

List of Figures

Figure 1: Invited Candidates by Professional Affiliation	124
Figure 2: Invited Candidates by Professional Distinction and Gender	125
Figure 3: Invited Candidates by Profession and Gender	125
Figure 4: Invited Candidates by Jurisdiction.....	126
Figure 5: Round 1 Delphi Participants, by Canadian Jurisdiction.	132
Figure 6: Round 1 Delphi Participants, by Professional Affiliation and Cohort	137
Figure 7: Round 1 Delphi Participants, by Jurisdiction and Cohort.	138
Figure 8: Expert Panel Member Self-Assessments of Review of Round 1 Summary Report	141
Figure 9: Sample Page of Round 1 Theme Summary for Expert Panel.....	142
Figure 10: Expert Panel Member Self-Assessments of Review of Round 2	152
Summary Reports.....	152
Figure 11: Word frequency analysis – Question 1 – Global Trends.....	163
Figure 12: Word frequency analysis – Question 2 – Foundations and Goals in Science Education.	164
Figure 13: Word frequency analysis – Question 3 – Barriers and Opportunities for a National Vision for Science Education.....	165
Figure 14: Word frequency analysis – Question 4 – Canadian Approaches to Science Education.	166
Figure 15: Word frequency analysis tree – Science for Sustainability and Global Citizenship	169
Figure 16: Word frequency analysis tree – Science, Technology, Engineering and Mathematics (STEM).....	170
Figure 17: Word frequency analysis tree – Scientific Literacy.....	171
Figure 18: Sample theme presentation and its justification as provided in Round 2.	237
Figure 19: Responses of Expert Panel to the 1984 Science Council of Canada Vision Statement	294
Figure 20: Responses of Expert Panel to the 1997 Council of Ministers of Education, Canada Vision Statement	294
Figure 21: Teaching Level Profiles of Expert Panel Members Actively Teaching.	314
Figure 22: Teaching Level Profiles of Expert Panel Members Not Currently Teaching.....	314
Figure 23: Most Significant Professional Lens of Expert Panel Members Teaching..	343

List of Appendices

APPENDIX 'A': Letter of Invitation to the Study.....	426
APPENDIX 'B': Letter of Informed Consent to Participate in the Study.....	429
APPENDIX 'C': Delphi Round 1 Questionnaire.....	439
APPENDIX 'D': Delphi Round 2 Questionnaire.....	446
APPENDIX 'E': Delphi Round 3 Questionnaire.....	466
APPENDIX 'F': Interview Questions Protocol.....	496

List of Abbreviations

AAAS	American Association for the Advancement of Science
BSCS	Biological Sciences Curriculum Study
CAQDAS	Computer Assisted Qualitative Data Analysis Software
CHEMStudy	Chemical Education Materials Study
CMEC	Council of Ministers of Education, Canada
NARST	National Association of Research in Science Teaching
NGSS	Next Generation Science Standards
NRC	National Research Council
OECD	Organisation for Economic Co-operation and Development
OISE	Ontario Institute for Studies in Education (University of Toronto)
PCAP	Pan Canadian Assessment Program
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PRQ	Primary Research Question (this study)
PSSC	Physical Science Study Committee
Q	Question from Round 1 Instrument (e.g. Q1)
QSR	Qualitative Statistical Research package (NVivo 10™)
RQ	Ancillary Research Question (this study)
SAIP	School Achievement Indicators Programme
SCC	Science Council of Canada Study
SSI	Socio-Scientific Issues
STS	Science-Technology-Society
STSE	Science-Technology-Society-Environment
TIMSS	Trends in International Mathematics and Science Study
UK	United Kingdom
UNESCO	United Nations Educational, Scientific, and Cultural Organization
U.S.	United States of America

THE LOGIC OF CONSENSUS ON THE FOUNDATIONS OF SCIENCE EDUCATION IN CANADA— A DELPHI STUDY

Chapter 1: Introduction

A Summary of Positions and Introduction to the Study

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, and; 3) the development of curricular frameworks in Canadian provincial jurisdictions. Though controversial, it will be argued here that Canadian schools, teachers, and students of science education have not had opportunity, historically, to engage in 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. The research of this proposed study is intended to bring to the surface the intentions, orientations, aspirations, and logic of consensus comprising a Canadian science education. The timing of the study, as will be demonstrated, is opportune. For the science education community in Canada, the study could be of significance as we go forward.

The very suggestion that Canada is not standing firmly upon its own science curriculum foundations invites energetic responses. For instance, Glen Aikenhead, Professor Emeritus of Science Education at the University of Saskatchewan holds fundamental disagreement with such

a position. Aikenhead maintains that “the old Science Council of Canada's 1984 science education study severed ties with the U.S. science education people, except for the accountability movement which doesn't believe anything exists unless you can put a number to it.” (Aikenhead, personal communication, December, 2013). Alternatively, it is offered here that if we look at the specifics of science curriculum design in Canadian jurisdictions in the post-1950s period, it is difficult to find other than a preponderance of American influences on science education in Canada. This is the case whether we speak of emphases, content, organization, contexts, scope and sequence of the disciplines, or certain pedagogical practices. Among the influences that can be identified, U.S. national academies of the sciences such as the National Research Council and the American Association for the Advancement of Science together with the National Science Teachers' Association comprise the principal directions eventually taken in the foundations of Canadian science curriculum over the period 1965 to the mid-2000s. Moreover, these influential stakeholders were responding - not on behalf of or with the broad consensus of the international science education community - but to the overtly political implications of periodic “national crises” (or the perceptions of crisis points) in the American education system. This history does not insinuate that such external influences on Canadian curriculum have created an unhealthy environment for science education in Canada. Indeed, most respected international benchmarking assessments of Canadian students' achievement in science (e.g., the Programme for International Student Assessment (PISA)) demonstrate that Canada's system of science education appears to be in good health.

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 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 the *Common Framework*). This pan-Canadian effort toward 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. 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.

By using an anonymous and asynchronous Delphi study method the research presented in this dissertation engaged a select and criterion-referenced community of expertise among Canadian science educators and practitioners in the sciences and related applied fields. The principal objective of the study was to determine, and perhaps give novel definition to, the foundations and goals of a uniquely Canadian approach to science education in Canada to the year 2030. Why 2030? 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 facility. Participation in a Delphi study, as we will have determined, involves an intense commitment over many months among the participants. The content of this dissertation includes: the background of the study; a statement of the problem and associated research questions; the significance of the study; guiding assumptions and limitations of the study; definitions of key

terms; anticipated contribution to knowledge; a brief description of the chapters in the dissertation; a literature review; a research methodology that addresses in some depth the Delphi method and its processes; instrumentation and procedures for data collection and analysis; in-depth analysis of the three-round Delphi round across a double cohort; a summary of the research, its conclusions, and proposed pathways for further research in the field.

Background of the Study

In recent years, Peter Fensham (2009) of Queensland University in Australia has presented arguments favouring the establishment of stronger links among researchers in science education, policy priorities that customarily generate curriculum frameworks in jurisdictions, and the politics of science education. In short, he suggests that in the absence of sound understanding of the political landscape that drives educational policy issues, there will continue to be a “record of naiveté about educational policy and the politics of science education itself” (p. 1080) on three fronts:

1. Development of new curriculum;
2. Not recognizing the contested nature of science in the curriculum; and
3. Exaggerating the generalizability of research findings and ignoring the limitations and complex realities of school science across schools, education systems, and entire countries (Fensham, 2009; p. 1080).

The coming together of curriculum policy, classroom practices, and science education research - for Fensham - provides at least two sets of suggested research questions; one set relates to curriculum policy as *values* and the second focuses on curriculum policy as *authority* (Fensham, 2009. p. 1081, *italics* my own).

Set 1: Curriculum Policy as Values

- Whose values about science education are favoured by this policy?
- Which stakeholders in society have been successful (most valued) in the shaping of this curriculum policy?
- Which groups in society are advantaged or disadvantaged by the practices that flow from this policy?
- Do our studies of practices favour conventionally disadvantaged groups, and who would then become disadvantaged if policy changes were to change practices?

Set 2: Curriculum Policy as Authority

- Where does authority lie in relation to curriculum policy?
- Which stakeholders have access to this authority?
- Where does the authority for changing practices lie?
- By whom and how is the link between curriculum policy and its intended practices monitored in the system of science education?

Fensham maintains that research into questions such as these is “still very rare in science education....[and] will require methodologies that are rather different from the range now commonly used”(p. 1081). For the purposes of the study conducted here, certain aspects of Fensham’s values and authority in curriculum policy hold interest (e.g., the relationships among stakeholders and their interplay with legitimate curriculum authority). As demonstrated in the methodology section of this dissertation, Fensham’s ‘requirement for different methodologies that are rather different’ was, for me, an opening. It was an opening for the assembly of an expert panel that is likely to be geographically, philosophically, and experientially diverse, but one that also collaborates anonymously and asynchronously through a Delphi process in the exploration of forecasting the future trends likely to affect curriculum policy-making. There are some compelling reasons for arranging for such a collaborative effort among members of the Canadian

science education expert community. Some of these are historical as just described while others include the rarity of assembling a large group which under typical circumstances is cost-prohibitive and idea-prohibitive.

When I look back upon the identifiable periods of science curriculum reform having shaped policy and practices in Canada since the 1950s, I am inclined to prefer the term “trajectories” in the sense that these episodes constitute new paths, a progression, or new lines of developed argument. The term also implies a crossing of paths or passing by the older order of thinking which does not dispense with former ideas while entertaining new ideas. For the sake of providing some historical demarcations, I include these ‘trajectories’: (1) science in the national interest which developed in the post-WW II period and came to international distinction during the post-Sputnik period, 1957-1970; (2) humanistic science education exemplified by the science-technology-society movement led by Canadian thinking of the 1970s and 1980s, and; 3) the outcomes, standards and international accountability thrust since the mid-1990s. It is noteworthy that visible characteristics shape each of the trajectories. For instance, the first and third trajectories were for the most part externally driven (from a Canadian perspective) by political/economic and science education policy influences. In a recent example, we can include foundational science curriculum policy documents that have held significant influence and effect in Canadian science curriculum reform such as *Science for All Americans* (AAAS, 1989; Rutherford & Ahlgren, 1989), *Benchmarks for Science Literacy: Project 2061* (AAAS, 1993; 2000), *Designs for Science Literacy* (AAAS, 2001), and the *National Science Education Standards* (NRC, 1996; 2012). Other science education policy initiatives have, arguably, paid plenty of attention to the inputs from a wide array of educational stakeholders, but not quite with the visibility of the documents just mentioned. Indeed, if we look at the bibliographic listings in

the Council of Ministers of Education, Canada *Pan-Canadian Protocol for Collaboration on School Curriculum: Science Learning Outcomes K-12* (CMEC, 1997), we find that this policy document's references include only one Canadian source – the 1984 Canadian Education Study (CES) conducted by the Science Council of Canada. Ten other curriculum policy references are dominated by inputs from Australia, the United States, and UNESCO. In order to find more significant recommendations from Canadian science education researchers, one consults the Suggested Reading section of the bibliography. Certainly this speaks to necessary and advantageous international collaboration and cooperation on science curriculum, but the Canadian instruments are offered a supporting role at best.

The science – technology – society humanistic science movement had certain Canadian science educators (e.g., Glen S. Aikenhead, now Professor Emeritus at the University of Saskatchewan) at the forefront internationally of a new set of influences on curriculum. To Aikenhead and certain of his contemporaries, this is thought of as a period when “Canada permanently parted company with significant American science education curriculum policy” orientations as recently articulated by Blades (personal communication, January, 2014). Other influences in curriculum policy such as the cultural, social, environmental, and individual learner demands present in the system constituted restricted voices. However, I believe that it can be demonstrated that Canadian science education reform – or at the very least that which influences reform - has not historically come forward from our own researchers, our own teaching community, our own major educational policy initiatives, nor has it been necessarily reflective of the Canadian mosaic and realms of experience.

Aikenhead (1999) insisted that a country must answer its curriculum questions for itself, and, for a country like Canada that is culturally, geographically, demographically, and

linguistically diverse it is perhaps more expedient that the curriculum pressures for reform come not from a society outside of us but from within. This is not intended to be viewed as a curricular parochialism but a recognition that an over-reliance upon exclusively international influences may not easily be mapped onto the Canadian experience. All three trajectories identified here were driven principally by U.S. curriculum policy interests or those developed through consensus with our socio-political or economic allies internationally. Again, this is not to in any manner imply that such external influences have not imparted a good measure of success to the architecture of Canadian science education. Put simply, I submit that Canada has never been in possession of a uniquely *Canadian* approach to science education and curriculum policy-making, the foundations of which can and should be clearly connected to the aspirations of its people and their place in the world dynamic. This study, in part, sought to determine if there is a Canadian context particular to science education, not a new nationalism or a focused action zone in Canada which would have the appearance of some form of national science education activism.

Statement of the Problem and the Frame for the Research Questions

In the chapter “Neo-Conservative Change: Old Reactions and New Ambiguities”, George S. Tomkins, in his *A Common Countenance: Stability and Change in the Canadian Curriculum* describes curriculum development in Canada during the period of the 1960s to the 1980s as a “pseudo-science” (Tomkins, 2008; p. 282). This characterization of curriculum development invites a brief comment. What could Tomkins have possibly been referring to when he used the term ‘pseudo-science’? I can imagine that it may have been a reference to the lack of Canadian-developed thinking with respect to school curriculum together with its presentation as a syllabus-

orientation in classroom settings - coming from elsewhere. Tomkins does not explicitly state what his intended meaning was for the term. However, there are some hints. He complained, for instance, that the process of education and the underpinnings of curriculum were dominated by American theoreticians such as Tyler, Bloom, Bruner, Ausubel and others. Tomkins goes on to claim, “as American curriculum models became accepted, and as the language of behavioural science came to permeate Canadian educational policy documents, indigenous (i.e. Canadian) development was characteristically neglected as revealed by the pitifully small resources devoted to it by provincial and local jurisdictions” (p. 283). Indeed, this study was able to determine that Tomkins’ ‘pseudo-science’ may be continuing by virtue of participants’ low self-ratings in judging their familiarity with seminal documents in the field of science education.

Tomkins’ retrospective appears to demonstrate some degree of identification with the notion that Canadian curriculum was never quite Canadian, but was a derivative curriculum. Perhaps this alone is the definition of his term ‘pseudo-science’ - that Canadian curriculum by virtue of being a derived from what was developed elsewhere, lent the appearance of being designed in Canada but was principally from the outside. To illustrate his point, he describes the Cold War science education system imperatives as coming to Canada in the wake of Alberta’s 1959 Cameron Royal Commission on Education, with the claim “Nothing less than national security, not to mention our standard of living, depend upon extensive and intensive science education” (Cameron Commission, 1959; p. 111). As a side note, the Cameron Commission devoted most of its remarks about science education in the chapter dealing with the future of Alberta’s petroleum production sector. A Council of Ministers for Education, Canada report - *Analysis of Science Curricula in the Provinces* - which was edited by Sharon M. Haggerty and E.D. Hobbs of the University of British Columbia (CMEC, 1981) confirmed that most Canadian

secondary schools were decidedly implementing science programming developed in the U.K. (e.g., Nuffield Science Project) and in the United States (e.g., PSSC Physics, CHEM Study, BSCS Biology and similar) and were just as firmly committed to curriculum through associated dedicated textbook series'. The CMEC report authored by Hagerty had two important (and polarizing) outcomes which assisted me in framing this study of Canadian science education: (1) It had identified a high level of continuity, agreement and commonality of the goals of science teaching among the Canadian provinces, and; (2) Outlined a general lack of Canadian perspective in science and technology, its history and impact on Canadian society by virtue of the externally-developed texts aligned with foreign curricula. Perhaps one more practical outcome could be added to these two. That is the almost immediate impetus the CMEC survey report may have provided to the opening up of the most significant inquiry into the state of science education – the Science Education Study (SES) launched in 1980 by the Science Council of Canada (SCC).

It would be difficult to understate the importance and the timing of the SCC science education study, not only as a landmark on the historical landscape of Canadian science education but also on the conceiving of this study. The SCC study was intended to shape a generation of thinking about science education through a thorough understanding of the views held by teachers of science and an analysis of current curriculum in Canada. This study, though far less ambitious in scope, wanted to broaden the perspectives on Canadian thinking by inviting many other key stakeholders into the process and be future-oriented. In my estimation this episode from the early 1980s warrants a brief synopsis, as the SCC study itself was founded on a search for greater Canadian identity in formal education that was rooted in the 1970s. In

addition, the SCC study will be repeatedly referred to in subsequent chapters in a variety of contexts.

Initially the proposal of James Page, a historian, the SES of the Council almost certainly received some inspiration from the earlier Symons Report of the Commission on Canadian Studies released in 1975. The Symons Commission was established at the annual meeting of the Association of Universities and Colleges of Canada at Winnipeg, Manitoba in 1970 (AUCC, 1975). The title of the report of the Commission on Canadian Studies – *To Know Ourselves* – was very telling and is somewhat apropos to this Delphi study. The title suggests 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 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” (AUCC, Symons Commission, 1975; p. 1). In the Report Rationale section, we read a daring and explicit 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). Conceived just three years after the Canadian centennial, 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 explicitly on the perceived lack of a Canadian perspective in science education and technology that it devotes an entire chapter to this one discipline area. Fully 34 of the 144 pages in the Commission report that are devoted to broad curriculum areas addressing the sciences and related technology fields.

Bearing the sub-title, *Is There a Canadian Science?*, one of the chapters in the Commission report provoked a spirited debate among the Canadian scientific community 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 position 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 Page for 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 1981 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 can be noted here that in the intervening period many Canadian science education scholars have made important contributions nationally and internationally in the pursuit of greater appreciation for the history of science informing science teaching and learning. What was observed by Page to be an area of neglect has certainly emerged as an area of serious scholarship and one in which Canada is a key collaborator. With this in mind, it is rather poignant that it was an historian (Page) – 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. At the time, there must have been a desire among the science education community to provide a rejoinder to Page’s assessment of the basis for a renewal in Canada – something complementary or challenging to his views. There was, and it took the form of what came to be known simply as the “Background Papers”.

In all, there were seven background discussion papers prepared by leading science education specialists for the Science Council of Canada to inform the beginnings of its 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 particularly agreed with another’s position nor did they have to as the collection was not designed around that purpose. The background papers were by invitation and were designed to engage 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)).

Taken together, the foregoing conditions of three decades ago aided immensely in providing firm foundation to one guiding assumption of this thesis study: Canadian science education can be characterised as a special case of the derivative curriculum that comes, not from ourselves and from within, but primarily from external influences over which we may have limited influence and control. Moreover, when we reached the 1990s and beyond - an era of significant increase in available resources and Canadian educator involvement in curriculum – it was suspected that this special case of the derivative curriculum has stubbornly persisted.

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 a science, technology, engineering, or mathematics (STEM) discipline. 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). Just to highlight the strong jurisdictional control of education in Canada and the bias that an international audience will experience in a report such as this, these authors were constrained to outline in detail the K-12 science curriculum in only one of the provinces – Ontario (p. 22-26). 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 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 and generate the research questions for the present study. First, there is the 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 ‘21st century skills’ and the growing preponderance of the STEM terminology in the science education literature ; secondly, the obstinate 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, where will we find and what will characterize 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? I use the phrase *logic of consensus* with some precision. The “logic” is an appeal to the Λογικός, the “*logikos*” which was the feminine mode of reason that forced decisions apart from or in opposition to the forces shaping the world (e.g., the Pythia at Delphi in Hellenic Greece). Seeking consensus, or the “*consentire*”, is here described as a collective opinion that is a “feeling of agreement” in the ancient physiological sense of a system of discrete organs that function together harmoniously while preserving their internal distinctions. Each time the reader sees the phrase ‘logic of consensus’ in this dissertation, this is the manner in which it should be viewed. And so, any ‘consensus’ that was sought after in this study was to be influenced much more by the strength of constructive opinion shaping the consensus rather than isolated opinion-making for its own sake.

As we will see in the literature review in Chapter 2, perceptions of a crisis in participation in mathematics and the sciences, or in student achievement in these disciplines, helped make manifest and launched the intense and pervasive post-*Sputnik* science educational reforms of decades past. The blame for the situation and the solution to the problem were both laid at the doorstep of two educational preoccupations – curriculum and teaching. In a recent op-ed article, David Blades (professor of science education and curriculum theory and the Director of the Centre for Excellence in Teaching and Understanding Science at the University of Victoria) claimed that teaching or curriculum in science are not notably responsible for the disengagement of Canadian youth from STEM-related studies (Blades, 2013). His critique of the system focused on what he viewed as “teachers trying to ‘cover’ a curriculum that was designed in the late 1960s and has not changed appreciably since” (p. 1). Blades called for a “nation-wide review and redesign of science curriculum in Canada” while noting that the last national-level study of science education in Canada had been concluded in 1984. That was a clear reference to the Science Council of Canada study mentioned earlier in this chapter (SCC, 1984 a;b). Blades closed his remarks with:

“We are overdue for a new study to broaden the benchmarks established in [Amgen Canada’s] Spotlight on Science Learning. Such a study will need the support from STEM industry alongside the inter-provincial will and cooperation to carry out the resulting recommendations. With such partnerships and determination, Canada should be enabled to maintain our tradition of innovation and leadership in science, technology, engineering, and mathematics.” (p. 1).

The 1984 Science Council of Canada study of Canadian science education referred to by Blades was indeed a landmark work in deliberative inquiry into curriculum policy in Canada – many would still be of the opinion that it was seminal and ground-breaking work that took full

advantage of sterling conditions for such a study to take place. That study was co-ordinated by lead investigators Graham Orpwood, Jean-Pascal Souque and their research team in order to produce a substantial report on behalf of the SCC, a federal agency created in 1967 (Orpwood, 1983; 1985; Orpwood & Souque, 1985; SCC, 1984 a;b;c). In a paper published in 1999, *STS Science in Canada: From Policy to Student Evaluation*, which was in part a critique of the processes and products generated by the most recent Canadian science curriculum framework (the *Common Framework*, CMEC, 1997), Glen Aikenhead of the University of Saskatchewan maintained that “the ‘experts’ were not adequately consulted or involved in the process of science curriculum reformulation” at that time in the 1990s (Aikenhead, 2000; [1999]). As recently as late in 2012, his position had not changed, claiming that:

“Curriculum policy making is always a political process. The trick is to reach a consensus among the stakeholders. That's where educo-politics comes in. For example, bureaucrats ignoring science education researchers to make the policy formation (curriculum) process appear to go more smoothly”
(Aikenhead, personal communication, December 7, 2014).

An intriguing series of questions can be posed if we accept many of the assumptions or positions outlined to this point in this chapter: “What would comprise the principal theoretical foundations and processes of a *Canadian approach* to the development of science curriculum frameworks”; “What if an ‘expert community’ involved in thinking about the future of science curriculum development was uniquely Canadian in its orientation”; “What if such an ‘expert community’ was poised to answer Canada’s science education questions for itself and from within its own unique set of national experiences”, and; “What if such an ‘expert community’

continued to collaborate internationally while maintaining a focus on serving Canadian interests, and was given voice in forecasting science curriculum reformulation to reflect Canadian aspirations?” (e.g., through the “consensus-making R&D” process as described in Aikenhead (2006; p. 130-131)).

The Purpose of the Study and the Research Questions

The central purpose of this dissertation study was to identify the system conditions and principal theoretical foundations to develop a Canadian consensus on science education in the post-Pan Canadian Framework period through forecasting to the year 2030. The study includes 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 the 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 an in-depth, anonymous, consensus-oriented and asynchronous process of inquiry. The inquiry – modelled in part on the hybrid Delphi methods of Landeta, Barrutia and Lertxundi (2011) – was conducted among an assembled community of science practitioners and science education specialists from many locations in Canada. The following primary question and its ancillary questions guided the research:

Primary Research Question (PRQ):

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 the post-Pan Canadian Framework period?

Ancillary Research Questions (RQn):

1. What trends and conditions – both domestic and international – will serve to initiate and have defining influence upon future science curriculum change in Canada? (RQ1)
2. What characterises consensus (or 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? (RQ2)
3. What characterises 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? (RQ3)

Significance of the Study

Connelly and Connelly (2013) made the following comment about the connection between curriculum (e.g., learning outcomes) and educational policy: “We make the point that *curriculum guidelines are policy documents* that perform two sets of functions, one set political and one set practical. They are documents that play an important role in political, public discourse over the aims, purposes and accomplishments of education, and they specify what is to be taught in schools, in what order, and in what relationships” (p. 54; *emphasis my own*).

Curriculum considerations, then, are at the very centre of the public educational process. Some 40 years ago, one of these authors (F. Michael Connelly) had concluded that these two sets of functions (the political and the practical) are oscillatory with each becoming more visible at certain points in time (Connelly, 1972). He adopted a curriculum oscillation model characterised by periods of centralized development by bureaucracies juxtaposed with periods of decentralized curriculum development to the point where it could be made to be an activity at the school level. Prescient and quite correctly, Connelly argued that such oscillations were manifestations of what he called “parallel oscillations among the psychology and needs of learners, subject matter, and social needs” (p. 162). I suppose that, ideally, there are periods where the harmonics of these three independent oscillations provide for a coherence and at other times periods of independent oscillation or outright dissonance. Connelly’s thinking set up an important thread for this study that lays exposed on the landscape of science curriculum development in Canada. That is, there were likely to be inevitable tensions that will occur and recur between curriculum development as a *political process* among those who are professionally accountable for curriculum, and curriculum development as an *educative and socialization process* among those who are

acknowledged as legitimate stakeholders but do not have the mandate of accountability. It was important for me to at least marginally subject Connelly's oscillation model of curriculum to a certain critical test. Such a test would act to determine if this curricular "tension" has maintained itself to the present and could hold for the next foreseeable period of science education in Canada. Alternatively, perhaps there was a basis for cooperation among the stakeholders and that certain of the 'tensile forces' are beneficial.

Connelly (1971; 1972) and Connelly & Clandinin (1988) viewed this dilemma, or persistent tension in curriculum origins and behaviour, as contributing to a system of education oscillations that are symptomatic of what was termed a "failure of curriculum development". They provided the following distinction: at certain moments in time the task of curriculum development is given over to the expertise of external developers and their general subject area knowledge, professional activities, or positions within society; at other times, it is teachers who are most directly involved in such development activity, and their expertise rests primarily with pedagogical knowledge and their facility with appreciating the demands of school life and children's learning. I suspect that the 'failure of curriculum development' alluded to by Connelly and Clandinin has more to do with irreconcilable differences between these two groups – an impediment to progress - as standing opposite to consensus-building that could stand a better chance of providing the willingness to succeed in curriculum. For me, this was a hypothetical position worth bringing to a test situation through an anonymous collaboration in the relative safety of an exclusively online environment.

In Canada today – led in a particularly visible manner by the OECD and its educational influences among its member countries – discussions about the relationship of science education, science curriculum, and the problematic terminology of 21st century skills sets and their

connections to anticipated economic considerations and international rankings are surfacing once more (see Amgen, 2012; Orpwood, Schmidt and Jun, 2012; UNESCO, 2008). It can be demonstrated that periodic concern about the state of science education, youth readiness and fitness for the state of the world economy, and international competitiveness are recurrent themes which have emerged and re-emerged in the last 60 years.

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 regularly asked to respond to the demands of influential external stakeholders. It is of interest at the very least to offer speculation that groups which are entitled to fulfilling the obligation of accountability in the education system are often respondents to – and not the initiators of – curriculum reform movements. This situation appeals yet again to the oscillation model just discussed where the political sphere and the educational sphere are not always able to cooperate fully. Some evidence for this has been provided by Orpwood (personal communication, December, 2013) as he provides the following observations from his experiences as an academic researcher who has worked extensively with bureaucracies in the Canadian provinces:

“[The] distinction becomes visible when we look at who the participants are in any project. One of the key ideas in the deliberative inquiry model as it was used in the Science Council of Canada study thirty years ago was that of stakeholders in science curriculum (drawing on Michael Connelly's work in that respect), but I also made a very significant distinction between two types of stakeholder, which I called 'insiders' and 'outsiders.' Insiders were defined as stakeholders with entitlement to a decision-making role and so included people from the Ministry, school boards, schools, and the classroom teachers. Outsiders by contrast were also stakeholders but whose roles gave them no direct authority to make decisions concerning science curriculum; these included employers, members of the science and

technology communities, university/college faculty, parents, and of course students themselves. One of my observations was that insiders traditionally clung tightly to their control of the science curriculum (the Pan-Canadian Framework development was a classic in this regard) and so in the Science Council study all deliberations involved equal numbers of outsiders and insiders. In particular the role of the so-called 'experts' is an interesting one. Technically they are outsiders because they are not part of the line structure in K-12 education, though they often have 'influence' (as distinct from 'authority') through their roles as teacher educators, text book authors, and in other ways.”

From there I sensed a need to explore the many implications of this from the perspective of Canadian science education specialists in order to determine what the current state of play was now that we are 20 years beyond the *Common Framework*, 30 years beyond the Science Council of Canada’s *Science for Every Student* (SCC, 1984c) and almost 60 years since the advent of *PSSC Physics* that became one of the iconic hallmarks of the post-*Sputnik* era in science curriculum. Earlier in this chapter, it was posited that “Canada has never been in possession of a uniquely Canadian approach to science education and curriculum policy-making”. Since such a declaration in my estimation was both provocative and perhaps testable, it was deemed an opportune point historically to convene an expert council of Canadian science educators (“insiders”) together with a distinguished group of the “outsiders” in order to consult on the issues that could arise. It was the probing of the Canadian context alongside where we are now in time and where we may be headed with respect to science education in Canada that the significance of the study rested.

Theoretical Frame, Guiding Assumptions and Limitations of the Study

According to the classical work on qualitative research methods of John W. Creswell (2012; 2013), a study's chances of being adequately replicated in another setting increases with overtly revealing the researcher's assumptions, limitations, personal biases, and the manner in which the study includes the researcher as one of the primary sources of data collection. For the Delphi method utilized in this study, virtually all of these considerations potentially apply. In addition to these considerations, I would argue that the theoretical frame for a Delphi inquiry relies significantly – both epistemologically and methodologically – on a constructivist variation of the classical *grounded theory* strategy of Strauss and Corbin (1990; 1994; 1998). In brief, grounded theory according to Corbin and Strauss (2008) provides the researcher with an opportunity to derive or abstract a new theoretical or practical position that is 'grounded' in the views of the participants in the study. The process, as summarised by Creswell (2013) involves “using multiple stages of data collection and the refinement and interrelationships of categories of information contained within the data” (p. 14) and demands the constant comparison of data with emerging categories and sampling of different groups to maximize the similarities and the differences of information. In my estimation, the Delphi method was well suited to bring forward the possibilities of consensus or disagreement by virtue of its iterative data collection sequences and refinements fed back into the participants' subsequent rounds of experience.

For this study, the following guiding assumptions were considered important:

1. The members of the council of experts are drawn from the Canadian science education community for the Delphi – and from among those who held strong interests for science education – and were chosen in accordance with certain select criteria which will be enumerated in a subsequent chapter; in the end I was aware that these individuals

comprised an *ad hoc* panel of volunteers which could only be *representative* of Canadian science education specialists and interest groups at a particular point in time; nevertheless, criteria for invitation (which are outlined in Chapter 4) included face validity by virtue of the traditions of Delphi studies dating back many decades to the 1950s.

2. At about the same time as the user interface for the world-wide web was emerging, Turoff (1991) advocated the use of computer tools for the purposes of conducting interviews and surveys for Delphi studies electronically via computer-mediated communication. Such usage today would be described as chat rooms, blogs, or discussion boards dependent upon whether the communication was synchronous or asynchronous. This study relied upon what proved to be successful asynchronous online communications techniques.
3. The responses provided by the panel of experts in the Delphi will not be considered to be inordinately influenced by other members' responses since the entire set of processes remained online, anonymous, and asynchronous (Shelton, 2010). Importantly, however, it is in the manner of a Delphi study to make syntheses of participants' responses available to all participants as controlled feedback during each round of questioning. Hence, movement of positions could expectantly result among the participants as a result of seeing the positions of others between rounds.
4. The expert panel members will have a natural interest in the research and its outcomes; this aspect can be supported by large volumes of emails provided by members that were unsolicited and sought clarifications on Delphi methods, literature threads to follow up on, and thoughtful statements of support for the research.
5. The researcher was to be embedded with practitioners in the process in a manner similar to that argued for thirty years ago by Orpwood (1983b). In that work, Orpwood was concerned with the question of how researchers can intervene appropriately in activities related to curriculum policy-making. He maintained that navigating between the extremes of an "imposition style" and an "abandonment style" could only occur effectively by understanding the nature of the problem at hand and by finding a solution to a common difficulty – credibility. Orpwood described two types of credibility, one for researchers

who were often university-based and theoretically oriented and another for practitioners who possessed deep knowledge of context and how the action would take place in a learning situation. This distinction is appropriate to appreciate given the professional experience I have brought to the study, including multiple episodes of working with science teachers in curriculum development. Which approach would be most effective for this study? In the end, since it was anticipated that participants in the study would include both theoreticians and practitioners alike, all seeking after some common ground, with some having entitlement positions and others not, the defensible course of action was to facilitate a coming together of a diverse set of voices and give those voices the freedom to interact. That interaction was to be the real centre of the Delphi experience.

The literature provides a number of cautions in the use of Delphi techniques, including recent doctoral dissertations using variant Delphi approaches such as Shelton (2010) and recommendations for greater quality assurances and research rigour (Hasson & Keeney, 2011; von der Gracht, 2012). Consequently, the following limitations of the study were considered notable:

- a) It was not entirely clear how methodological rigour should be established with Delphi as each study's research design, sample of expert participants, and consensus/dissensus processes is unique (Hasson & Keeney, 2011);
- b) Opinion-making in the Delphi is neither a static process nor consistent across spatial scales, and so confounding variables such as the current situation, person-specific factors, and measuring consistency of opinion are recognized but rarely controlled for in the Delphi (Woudenberg, 1991). This study, then, can be viewed as a moment of expert opinion and idea-making among decades of experiences in Canadian science education; but that did not constitute a reason to discard the rarity of the opportunity;

- c) Much of the literature of Delphi studies recognizes the limitations inherent in the technique for measuring consensus (Landeta, 2006). There is far less research and analysis that focuses on dissent rather than consensus (e.g., policy Delphi (this study) or the emerging dissensus-based Delphi methods (Steinert, 2009)). In recent years, there has been increasing numbers of Delphi studies that are specifically designed to stimulate structured conflicts in order to expose opposing views and provide a focus on dissent-oriented analysis (Von der Gracht, 2012). This study conjectured that the use of provocative question formulation, exposing alternate future projections for Canadian science education, and managing the emergent conflict among the expert panel members raised an important caution;
- d) At the time the study was proposed in September, 2013, there was no agreed-upon framework for valid Delphi facilitation despite the large number of studies utilizing the technique – including an end-point policy for Delphi rounds. It was my task to determine when an appropriate level of consensus/dissensus had been reached (Hsu & Sandford, 2007a). In addition, an exhaustive, ordered, comprehensive critical list of measurements of group consensus on one hand, and of group stability on the other, that looks closely at specific variables (e.g., type of question to be answered, number of variables, scales of measurement, and categories of experts) remained elusive (Von der Gracht, 2012);
- e) The researcher remained constantly aware of identifiable biases that may intrude on the Delphi study and so inadvertently slant the results in the direction of researcher desire. Recently, Ecken, Gnatzky and von der Gracht (2011) noted that desirability bias could make experts' estimates of their position diverge and thus impede achieving an actual consensus. Such potential biases were accounted for in the interpretation of the data in

this study but could not be tightly controlled; it remains important to understand that Delphi shares many of the characteristics of any other oversight group, panel discussion, chat room and so on but has traditions of structure that ensure that all the voices who wish to provide input are afforded that opportunity (i.e., controlled feedback into the system by the lead researcher);

- f) Helmer-Hirschberg (1966;1967), one of the founders of the Delphi method at the RAND Corporation, noted the phenomenon of polarization in the data as potentially being an indication of two possibilities: opinions are based on different data sets, or, alternative interpretations of the same data set; this study discovered that the provision of *operational definitions* of the many terminologies involved in science education was beneficial just as often as the absence of direction proved a difficulty for participants; in many such cases, expert panel members provided for their own situatedness;
- g) To control for researcher bias, it was recommended in the dissertation proposal that a third-party, independent auditor be engaged to assist with examining data analysis of the researcher; and, to conduct a pre-test (field validation) of the initial questionnaire among an independent panel not participating in the study but satisfying the selection criteria of the expert panel; the former was deemed impractical nor necessary and the latter was not conducted due to the timelines set out for the study;
- h) Shelton (2010) discovered that “because of the time required to gain consensus, and several survey rounds may be needed, the possibility of low response rates from panel members exists” (p. 10). A mechanism to examine the nature of, and the rationale for, non-response was thought to be required in the study in accordance with the recommendations of Hsu & Sandford (2007b). To assist in minimizing non-response,

Keeney, Hasson and McKenna (2006) recommended that the researcher consistently remind the expert council members of their importance to the study, that the process is based solely on the quality of their engagement and responses, and reliability of responses and their timeliness is critical to the success of the study. Rieger (1986) recommended that the response rates must exceed 95% for the study to be effective, and that drop-outs needed to have opportunity to be questioned about the reasons for their withdrawal; this study regularly maintained response rates exceeding 95% for each round and deleted previous rounds' data upon the exit of any member of the expert panel;

- i) All researchers who embark upon a Delphi study need be cognizant of the strident opposition to the technique by Sackman (1974a; b) who was also a RAND Corporation researcher. His opposition was largely due to his positivistic inclinations to an 'objective, external, controlled reality' that in his view would necessarily elude the Delphi inquiry technique. Successful rebuttals to Sackman (e.g., Goldschmidt, 1975; Linstone & Turoff, 2002; Ziglio, 1996) provided support for research studies for which the technique is well-suited such as those addressing policy issues that cannot be easily explored by conventional quantitative methods, and for those inquiries that are not well-positioned for classical, psychometric methods. Perhaps the most important limitation (to avoid) is a Delphi study that is inappropriately designed or implemented (Rieger, 1986); that judgement is reserved for the review committee;
- j) The decision-making process of the researcher, according to Delbecq, Van de Ven, and Gustafson (1975), could face inhibition or obstruction from: (1) social-emotional rewards not being present leading to a sense of detachment from the expert panel at times when the researcher would prefer to be immersed in the flow of data as a co-participant; (2)

since verbal clarification of the responses in the Delphi being fed back into the expert council members (for subsequent rounds) is usually not provided, there can arise difficulties in member interpretation and communications, and; (3) group priorities in the Delphi are customarily determined from the majority responses, and so dissent, conflicting interests, and irreconcilable responses must be carefully weighed in the balance by the researcher; in this study, being aware of disagreement among participants' views was just as important as recognizing movement to consensus positions.

Contributions to Knowledge

Based on the research questions, the stated objectives of the modified policy Delphi study approach to the research, and the complexion of the assembled expert panel on Canadian science education, I can provide the following outcomes of the study:

1) This Delphi study is a first-of-kind comprising an expert community of Canadian science education specialists, allied science researchers, and those actively engaged in the public understanding of science. Significant levels of consensus were reached in a complex area of inquiry such as forecasting the future foundations, goals, assumptions, and aspirations of science education in Canada (as was the case in the nature of science Delphi research of Osborne *et al.* 2003) when this was thought to represent an elusive and perhaps illusory goal. Since the policy Delphi approach invites open dissent and is intended to produce numerous policy options, an emergent dissensus on certain issues was viewed as being as informative and constructive as any modest or strong consensus positions.

2) I came to know the understandings, values, and intellectual commitments of a rich cross-section of practitioners in science practice and science education in Canada. Given the guiding assumptions that Canada: (1) had not had access to future-oriented thinking in science education of this type in a number of years; (2) had not had a national-level consensus (without a bureaucratic emphasis) leading to a framework for the foundations and goals of science education in 20 years, and; (3) not had opportunity to construct a new consensus (or dissensus) on science education in Canada from an assembly of the expert research community done anonymously and asynchronously; the prospects now are in place to inform a succeeding generation as to how Canada proceeds into the post- Pan Canadian Framework era.

3) I came to the realization that a unique Canadian approach to science education is possible within the constitutional setting of Canada as a federation. It is rooted in its traditional peoples' voices, its varied landscapes, and a vision for science education that calls for active, democratic citizenship. By virtue of the understood constitutional guarantees in setting the agenda for education, this Delphi process determined that inter-jurisdictional consensus, compromise, and collaboration can be served and is actually desired; in this study, it was modeled by an assembly of the science education expert community of stakeholders. The knowledge base provided in succeeding chapters of this dissertation can be presented as points of discussion and points of departure in the next (and inevitable) period of science education reform in Canada.

These findings

will contribute to national and international discussions and emerging commitments to science

education in going forward, and will provide insights into framework and model designs often requested as support for science education policies, guidelines, curriculum development, teaching strategies, professional development for teacher education (in-service and pre-service) and other innovative educational practices.

Although generalizability was not the immediate purpose of this mixed-methods semi-quantitative / qualitative research, the understandings of the Canadian expert community herein offer both a ‘moment in time’ and impetus for moving forward. These research findings will be communicated both within and outside of the academic community and among a variety of science education stakeholders nationally. I operate as a provincial government science education consultant who must carefully bridge the political and the practical in science education.

Organization of the Study

This dissertation is organised into the following chapters: an Introduction which comprises the background of the study; a statement of the problem and research questions; the significance of the study; guiding assumptions and limitations of the study; and; contributions to knowledge. Chapter II presents a review of the literature in Canadian science education with an emphasis on periods of curriculum reform and a sequence of “curriculum trajectories” over the period of the 1950s to the present. Chapter III comprises a complementary literature review on the historical development of the Delphi method of futures forecasting among experts, the use of Delphi techniques in studies in education and education policy, and the policy Delphi variant and

its appropriateness to this study. Chapter IV describes the research design and methodology for the study (modified policy Delphi), its modifications and adaptations to issues in science educational policy-making, the instrumentation and procedures, and procedures for data collection and analysis. Chapter V comprises syntheses and analyses of the data collected from Rounds 1, 2, and 3 in a general manner and addresses the system conditions and global trends thought to be significant in shaping, influencing, and initiating science curriculum change in Canada going forward. Chapter VI of the Delphi comprises syntheses and analyses of the data collected from Rounds 1, 2, and 3 and addresses the theoretical foundations and goals for the science curriculum in Canada as these have emerged from the deliberations of the expert panel in two cohorts. The results are systematically organised around the research questions. Chapter VII provides a summary of the research results, a discussions of their significance, provides a synopsis of expert panel consensus positions, makes recommendations for further research efforts, and includes possible practical ways of taking the research results to initiate new developments in the Canadian jurisdictions. Interventions in the data from semi-structured in-depth interviews, conducted after Round 3 of the Delphi, serve to clarify certain *representative* members' positions with respect to the major themes emerging from the study. Their anecdotes are incorporated throughout Chapters V to VII where appropriate for support of the expert panels' findings and for triangulation. The thesis concludes with a bibliography of references cited from the literature, relevant appendices comprising key activities of the study such as the instruments used with the expert panel and interview protocols.

Chapter 2: Literature Review I – Science Education in Canada

Science Education in Canada 1957 – Present: An Overview

For the purposes of examining movements in Canadian science education which are believed to provide the historical foundations for present-day science education in Canada, I have selected the post-World War II time frame. More specifically, the period of 1957 onward. This allows for the literature review to discuss certain of the ‘trajectories’ of science curriculum reform which have been identified as having some effects on Canadian science education. Why begin with the period after the Second World War and the emergence of the Cold War period? Prior to WW II, science education in Canada was rather amorphous and lacked high status knowledge in its K-12 systems of education. The rapid technological advancements made during WW II, the subsequent post-war “baby boom”, and the prospect of international science prestige being at stake with the onset of the Cold War all provided impetus for rapid change in systems of education. The world had changed, permanently. Inevitably, so did science education.

In the forward to George S. Tomkins’ *A Common Countenance: Stability and Change in the Canadian Curriculum*, considered by many as a classic historical treatise on Canadian education, Neil Sutherland (2008 [1986]) opens his synopsis this way: “Tomkins has written what is obviously one of the seminal books in the history of Canadian education. With *A Common Countenance*, the history of curriculum in Canada takes its place as a new and important field of academic inquiry” (p. xxvi in Tomkins, 2008). In the Introduction to the 2008 re-issue of Tomkins’ original, William Pinar described the work as “not only canonical for Canadian curriculum specialists, the book is also necessary reading for all prospective and practicing teachers in Canada” (Pinar, 2008; p. 131). In Tomkins’ historical assessment of

science curriculum in Canada, he (unlike so many of his contemporaries) managed to not adopt a common misrepresentation of the public anxiety over the 1957 launching by the Soviet Union of the satellite *Sputnik* as something to be laid at the doorstep of public education in general and science and mathematics education in particular. More recent accounts of the era provide evidence that *Sputnik* was simply the iconic representation, or the archetype, of a perceived malaise in the American education system (Kaiser, 2006; Urban, 2010). In that period, the Gordon Commission on Canada's Economic Prospects presumed a scientific and technological gap between the Soviet Union and the Western economies as did so many other clarion calls for educational change. Tomkins explained, "As in that country [the United States], national shortcomings were laid out at the door of deficient school curricula and related educational neglect" (Tomkins, 2008; p. 265). Rightly so, Tomkins noted that the launching of *Sputnik* was not the initiator of curricular reforms in science and mathematics in the Canada of the 1950s, as reconstruction of a discipline-centred and subject-specific curriculum was already underway. This is a common misunderstanding, and has led to many unsubstantiated commitments that it "was all about *Sputnik I*" (Urban, 2010). Nevertheless, the Soviet Union's achievement was certainly the most luminous event – if not the critical incident - in a decade that understandably sharpened the focus of reform in a manner that had had no historical antecedent. At this point, we will look more closely at the trajectories of science education reform in Canada and how these provide the basis for new considerations of where the next generation of thinking might take us as a result of opinions from the study participants.

Trajectories in Science Curriculum Development

MacPherson (1999) provided an insight about the behaviour of research in the social sciences. He claimed that the social sciences (including education) had a long history of “reifying metaphors from elsewhere” as a means of applying theoretical positions from outside the social sciences to its own purposes (e.g., identifying law-like behaviours in a system). The “bad news” in this for MacPherson was that “all such attempts [at reification] will inevitably fail, but may become useful metaphors” (p. 67). At the risk of perpetuating this tradition among the social sciences, I will construct a metaphor for science education but with Schwab’s admonishment that such models can act as metaphors that have potential usefulness if explored. The metaphor which I find attractive for science curriculum development in Canada can take the form of a *ballistic trajectory* rather than the oscillating pendulum of Connelly (1972) and for this reason: it is asserted by this researcher that matters of science curriculum are best described by ‘bounces along a path’ rather than the periodic oscillations of a pendulum. One is iterative, the other bi-polar and restrictive. A ballistic trajectory implies a path, a progression, a line of development over time and begins with an identifiable moment in time when a particularly fresh and novel set of conditions ‘launches’ a new phase of curriculum development, usually in response to an visible set of societal pressures of one kind or another. This initiating phase is then followed by a period of ascendancy where the theoretical commitments, policy drivers, resources and temporal concerns of educators converge to re-shape the landscape of curriculum. This is all considered as very intentional and planned. Over time new pressures upon, concerns about, and possibly dissatisfactions with, the present state of curriculum cause a particular trajectory of curriculum to experience a period of decline to a point where – to avoid disappearing altogether from the scene – it must be re-energized with a new ‘bounce’. A new set

of conditions re-invigorates the path, an appeal is made to what used to be, and sharp criticisms are levelled at the competing trajectories (MacPherson, 1995; 1997). Another advantage of the ballistic trajectory model is that more than one curricular paradigm can be operating at any one time, and so there can be overlapping trajectories, some undergoing steep ascendancy (such as Piagetian constructivism (theoretically), and outcomes, standards, and international rankings (practically) in the current educational environment) while others may be in a long, low-angle trajectory such that they never seem to lose position in curriculum and instruction (e.g., academic rationalism in science education, or science-technology-society).

Trajectory 1 - A Sense of Urgency: Post-Sputnik Era and Science Education in the National Interest

There is perhaps no more widely accepted demarcation in the last century of science education than that which came before the early days of October, 1957 and what came after. Recent work among historians (Mieczkowski, 2013; Wang, 2009; Urban & Wagoner, 2008); historians of education (e.g., Tomkins, 2008 [1986]; Rutherford, 1997a;b); science education policy-makers (Krige, 2000) and many science educators who have lived in the post-World War II period cannot conceive of a science education other than prior to this date or what followed it. For those who were living at the time of the USSR launch of the *Sputnik* satellite, it likely provides a singular moment for which they have remembrance of where they were when they first heard the news of its success. Science educators and curriculum theorists alike point to this episode in the history of aerospace technology as a tipping point for science and mathematics, or at least a fulcrum. It argue here that this demarcation point is much more diffuse than we have

been led to believe, and that the *Sputnik* moment was simply the most visible manifestation of many years of concern in the United States over the ability of the (then) Soviet Bloc to train ever larger numbers of scientists and engineers. Even if this moment in history has been oversold to those dedicating themselves to science education, it is worth recognizing that the period of the 1950s and 1960s was characterised as a period of rapid transformation in our views of what drives the project of science education. This episode is iconic from the standpoint of igniting science in the national interest for Canadians as well as Americans, a catalyst for change which was to recur in the early 1990s with the publication of *Science in the National Interest* (Clinton and Gore, 1994).

Just what were some of the visible symptoms of the post-*Sputnik* period? In a recent and provocative analysis of the behaviour of the American physics community in the 1950s, Kaiser (2006) makes some remarkable claims. These claims include: physicists became directly involved with investigations into the Soviet educational system, primarily to determine its ability to produce disproportionate numbers of scientists and engineers, and; there were efforts to learn how Soviet scientific workers used their time by making available to the English-speaking world the contents of their leading research journals in translation. Kaiser concluded that an emerging fear mobilised and perhaps politicised the American physics community at the time, worried that the USSR had subjugated all its other interests in education to pursue a techno-militaristic state. The reaction was that a number of studies of the Soviet system began to appear as early as 1954 and certainly may have played a role in increasing educational anxiety in the West.

Alexander Korol, a Russian expatriate working at the Center for International Studies at MIT, published a report *Soviet Education for Science and Technology* (Korol, 1957) that, among other qualities, gauged the content and quality of Soviet pedagogical materials and the academic

standards of their science academies. This report appeared just weeks after the Sputnik success. A few years earlier, DeWitt had published a paper on the current state of professional and scientific personnel in the USSR to a wide audience, and had completed a report to the National Science Foundation on Soviet education and training (DeWitt, 1954; 1955; 1961). And so, well before Sputnik significantly elevated the consciousness of America and its NATO allies (including a very interested Canada) to the importance of a focus on education and training for future scientists and engineers, the emergence of a nuclear science infrastructure in the USSR was now added to the prospect of a ballistic missile to carry a warhead – and this all in one week in October, 1957.

In addition to the rather immediate impact that *Sputnik* had on the American consciousness and the attendant sense of inadequacy and foreboding in science and technology-related education, there was an equally important set of conditions that were extant at that time. One of these was the founding, under President Eisenhower in 1960, of the President’s Science Advisory Committee (PSAC). Not long thereafter, having observed that Vice-President Richard Nixon had been narrowly defeated by John F. Kennedy less than a month earlier, some became convinced that the PSAC was inaugurated to provide American society with a level of protection for science, a means by which nascent educational reforms could be supported – particularly those of the National Science Foundation – and act as a safeguard against the prospects of Democratic Party liberalism under the new Kennedy administration. There were significant public educational consequences of *Sputnik*, including the humiliation as Americans watched their own ballistic missile program experience some spectacular and very public setbacks in its early trials. One could say that these ‘consequences’ were unexpected, unplanned, and took shape quickly.

In 1958, the U.S. congress passed the National Defense Education Act (NDEA) that provided an opportunity for the underfunded U.S. educational system in many areas of that country to tie together federal aid to education, improvement of impoverished school districts (particularly in the American south), and academic deficiencies into a narrative driven by Cold War rhetoric and the startling fact that the U.S. could be falling behind. It worked remarkably well (Urban & Wagoner, 2008). With unprecedented federal aid being provided to American schools, and to the support of science and technology through fellowships and loans to students, there were two other significant, though corollary, effects on the system of education – school curriculum reform and the concept of *science literacy*. The reform and re-conceptualization of science curriculum in the post-*Sputnik* era included other contributing factors society-wide that would have additionally been responsible for supporting such reform, not the least of which was funding to new programs and questions being asked such as “what kind of education in science is needed to cope in a society of rapid technological change?”.

In 1958, at about the same time preparations were being made for science reform-inclined scientists, educational psychologists and other interested parties convened the seminal conference at Woods Hole, Massachusetts, Paul Hurd of Stanford University wrote a brief article in *Educational Leadership* entitled *Science Literacy: Its Meaning for American Schools* (Hurd, 1958). In that article, Hurd attempted to argue persuasively for a new kind of literacy, articulating that:

“Attempts to define human values, to understand the social, economic and political problems of our times, or to validate educational objectives without a consideration of modern science, are unrealistic. More than a casual acquaintance with scientific forces and phenomena is essential for effective citizenship today. Science instruction can no longer be regarded as an intellectual luxury for the select few. If education is regarded as a sharing of the experiences of

the culture, then science must have a significant place in the modern curriculum from the first through the twelfth grade.” (p. 13).

It could not have been said more explicitly; science education was to change imminently and there were powerful arguments to sustain that change. The drivers were galvanizing almost every segment of American life towards a new, more sharply defined and narrower focus on science education. By natural extension, this new focus was also to act in solidifying the common positions of NATO allies (Livermore, 1964). Johnson (1962) echoed many of Hurd’s sentiments about the need for a new literacy in science, and made an attempt at a definition of the term. The freshness of the definition is notable:

“The concept of scientific literacy must be based, first of all, on a kind of knowledge that is much broader than mastery of detailed information. It suggests [also] the qualities of curiosity, accuracy of observation and interpretation, and open-mindedness. The person who is scientifically literate will be curious about the how and why of materials and events. He (sic) will be genuinely interested in hearing and reading about those things that claim the time and attention of scientists, and that interest will not be lessened by unwelcome ideas or events. Such a student may never create any ideas pertaining to science, but will be conversant with the ideas that are being considered in the intellectual marketplaces of the world.” (Johnson, 1962; p. 239).

Later on in his 1958 article, Hurd presciently predicts the neo-liberal forces of economic globalization by saying “can a philosophy of education be developed and a curriculum invented that will prepare young people for the approaching era of world cooperation and industrialization?” (p. 14). He sensed that the “scientific age” was unfolding so rapidly that the pace of that change would overwhelm formal education systems if there were not a move to a

“new look” in education. At that time (and we are reminded that Hurd was writing in 1958) he noted that the science curriculum and its textbooks were already demonstrating signs of contributing to an overburden of content, having little in the way of opportunities for students’ “depth and quality of understanding”. Hurd also projected that “it will be most difficult to discard those sections in our courses which have been taught for so many years that they appear to be forever fundamental.” (p. 16). That point raised by Hurd’s thinking immediately invites the possibility of J.A. Peddiwell’s (1939) allegorical and satirical *Saber-Tooth Curriculum* as mirroring the science curriculum.

The Structure of the Science Disciplines

The actions that took place in the period 1957 to the late-1960s were staggering in their scope – over 50 national committees were convened to alter curriculum and instruction, university science departments were engaged in the development of teacher education courses, and of course in 1961 Jerome Bruner had just penned *The Process of Education* which was to be a sort of manifesto for academic rationalism, the structure of the disciplines, and eventually a massive uptake in the development of classroom-based materials that actually *constituted* the nature of this science curriculum reform period. Projects such as Harvard Project Physics, the Physical Sciences Study Committee (that gave us, among other programs, PSSC Physics), the Chemical Education Material Study (CHEMStudy), the Earth Sciences Curriculum Project (ESCP), the Biological Sciences Curriculum Study (BSCS biology), and the spectacularly successful Introductory Physical Science Program (IPS); all of these are among the archetypal and iconic examples of the sorts of “teacher proof” materials that had wide adoption in the U.S. and Canada. Teaching and learning resources *were* the curriculum, and if we accept that

curriculum is a statement of policy, then the National Science Foundation was leading the curriculum reform in the 1960s with the full support of the National Science Teachers' Association (NSTA, 1964). It is worth noting, however, that the first of these ambitious projects (PSSC Physics) began its work in 1956, more than a year prior to the influences evolving out of *Sputnik*.

In the wake of all this, yet a new voice was heard in earnest for the first time in the wake of the NDEA, that of those who had advocated for special programming among gifted and talented students. Passow (1957) and Passow, Beasley & Brooks (1957) were supportive of individualized programs and accommodations for 'rapid learners' in mathematics, the sciences, modern languages, and technology. For over 40 years Passow continued in his advocacy for talented students and talented teachers (Passow, 1993) and the echoes of the effects of the NDEA are still with us today among those who maintain that gifted education perceptions fluctuate in accordance with apparent needs for the abilities and talents of 'high ability students' (Jolly, 2009). If we combine the NDEA, the PSAC, the Woods Hole Conference, Brunerian structured approaches to the disciplines, novel and nuanced learning resources developed by academic specialists, and the efforts of instructional and educational psychologists all coming to bear on curriculum reform, it set the stage for either a veritable revolution in education or an inglorious failure in curriculum design at great cost to the system. These were the authoritative voices of a strongly ideologically-driven period with significant investment in the national interests, and they were not necessarily the voices of the end-users of curriculum, teaching and learning – the teachers, students, and parents.

What happened with the teachers? It is generally accepted, in hindsight, that one of the principal difficulties that faced the “alphabet soup” matrix of curricular resources mentioned in this section of Chapter 2 is that of a disconnect between the intentions of those who were the developers and the actualization of those intentions among teachers and learners in the field. These resources were replete with exhaustively detailed implementation schema and instructional strategies for teachers. Quite surprisingly, after almost a decade of implementation into the early 1970s there was virtually no evaluative work accomplished on these curricular initiatives by educational reviewers and researchers (Connelly & Orpwood, 1977). Herron (1971) did accomplish a detailed study of teachers’ understandings of the conception of inquiry for cohorts who were implementing BSCS Biology, PSSC Physics and CHEM Study and had attended a summer program sponsored by the National Science Foundation. Herron found that in the majority of cases there was a complete disconnect and minimal correspondence between the intentions around inquiry as goals in these new curricula and what could be exhibited by these cohorts of teachers. Somehow, the content knowledge seemed robust enough, but teacher conceptions of the nature of science were naive and almost indistinguishable from untrained teachers. All that this may demonstrate is that, as Connelly (1971; 1972) pointed out, “teachers are highly autonomous agents with respect to externally developed materials.” (p. 164; in Connelly, 1971).

In order to provide a curious juxtaposition between the major policy drivers listed earlier (eventually becoming curricula for science in the national interest) and the answers that would be provided to the question “What were schools for in the post-*Sputnik* period?”, the following sentiments of the period are illustrative. Spalding (1958) indicated that “questing students with an inquiring mind are man’s (sic) best defence against the forces of cruelty and coercion” and;

the concerns expressed by the scientific community about the possibility of becoming limited, “captive scientists” by narrowly-focused, defence-oriented science policy were not shared at the political level. His concern was that public educational policy was being shaped more by the Department of Defense and by the U.S. Congress than by the scientists and educators of his time. Hass (1961) identified prominent roles in curriculum development to scholars, lay citizens (e.g., parents), student-teacher dyadic planning, and a significant role provided for teacher leadership at the local level in providing a justification for the implemented curriculum.

This discussion of science in the national interest and the structure of the disciplines incorporates many of the curricular foci and tensions that exist today, for instance: (1) arguments over the ultimate purposes of an education in the sciences; (2) who (or what institutions) is (are) responsible for deciding on the content and design of curriculum; (3) the struggle for contemporary socio-scientific issues to find a place in the science curriculum; (4) the role of science education in shaping responsible citizenship, and; (5) whether the production of a scientific élite is still an important priority and purpose of science education in Canada. These considerations, and others, were front of mind when the Council of Ministers of Education, Canada sought to assess the state of play in Canadian science education as the decade of the 1970s closed and the 1980s began. That SCC study proved to be a critical period of inquiry into Canadian science education, attempted to set the stage for a flourishing of science and technology education in Canada, and there has not been a study of its kind since. In the next section, an examination of a second trajectory - science, technology and society (STS) and the emergence of science literacy - we will see the increased visibility of the ideologies of progressivism, liberal values and the humanistic in science education. The roots of this next period of science curriculum reform are to be found in the earlier period; it simply required time

and changing societal conditions to create the convergence of values necessary for yet another kind of education in the sciences.

Trajectory 2 - Science, Technology, Society and Environment and the Re-Emergence of Science Literacy

By the early 1970s there was growing discontent over the manner in which the curriculum materials of the 1960s were being implemented in schools and their effect on the character of science education. Their general acceptance was impeded by a host of the typical factors that can cause resistance to change, among them the perceived loss of technology considerations and the applications of science, deeper inquiry having replaced the former broad-spectrum survey approaches to science education, and the growing societal disenchantment with science and lack of emphasis on the social and humanistic considerations that many educators felt were ideologically important (Rutledge, 1973). Writing at the close of the 1960s, Klopfer (1969) sketched out an interesting and quite prescient view of science education in his article *Science Education in 1991*. He chose that year as his benchmark ostensibly because that represented the beginning of the last decade of the 20th century and it was thought that some ‘millennial’ speculations were worthwhile. In that article, Klopfer predicted the following attributes characterizing science education:

- There would be a discrepancy among the goals of science education as deemed appropriate for different groups of learners;
- The seemingly narrow and restricted conceptual schemes of science curriculum in the 1960s with an emphasis on pure science knowledge in discrete disciplines would give way to the ‘big ideas and major conceptual schemes’ that we would recognize in the present day as relativity, systems interactions, and concepts of force;

- There would be continued tensions between advocates of academic science and those who encouraged the applications of science and its role in modern society;
- Secondary-level science education would be asked to shoulder an ever-increasing content-laden approach, and that the preparation of students for post-secondary science courses would pre-occupy educators to the point where that preparation for advanced study would become the primary aim of high school science teaching;
- The process of scientific inquiry would provide the major emphasis in education for scientific literacy;
- An understanding of the interactions between science and the general culture would eventually be considered as crucial to scientific literacy;
- Science in secondary schools would increasingly become differentiated into two streams – the Prospective Scientist stream (PS) and the Scientific Literacy stream (SL), and that differentiation would selective ‘stream’ students by age fourteen;
- The K-8 spectrum would be a “science for all” approach characterized by increasing levels of sophistication in basic science;
- The “goals of science education appropriate for everyone in schools and colleges are those which will contribute to the individual’s scientific literacy” (p. 201).

For those who may have begun their tenure in science education in the early 1990s, virtually every one of Klopfer’s attributes rings true. It is also remarkable that the seeds of curriculum reform – or at least calls for reform - that we will outline in this section in Trajectory 2 were already in the ground at least a decade before they were popularized in the literature and discourse in science education.

In Canada, the emergence of the science-technology-society (STS) triad as a novel driver in curriculum together with notions of a broader scientific literacy are difficult to separate – temporally or spatially. Each in its own manner holds up a mirror to the other insofar as to have a

desire for science literacy is quite reflective of the necessity for making STS an emphasis in curriculum development. This change in the Canadian science education landscape took shape in the early 1980s and is perhaps best articulated by the contributions of Douglas Roberts, who – at the same time that the Science Council of Canada was posturing with its major findings to be released in its *Science Education in Canadian Schools* – articulated seven possible ‘curriculum emphases’ for science in schools (Roberts, 1982; 1983). Presented below are Roberts’s seven-fold emphases, distinguished as VISION I and VISION II science education:

VISION I:

- *Solid foundations* -- to prepare students for the next level of science courses;
- *Correct explanations* -- to learn the truths (sic) of scientific knowledge;
- *Scientific skill development* -- to learn the conceptual and manipulative skills required for participation in scientific inquiry;
- *Structure of science* -- to learn how the academic side of science functions as an intellectual enterprise and to see the conceptual harmony that a scientist sees;

VISION II:

- *Self as explainer* -- to help students in their personal efforts to explain natural phenomena and to make personal sense out of the nature of scientific explanations;
- *Everyday coping* -- to help students understand important objects and events in their everyday lives; and
- *Science, technology, and decisions* -- to become aware of science in a social and technological context.

Aikenhead (1999) was of the opinion that the last two curriculum emphases argued for a significant Science-Technology-Society (STS) approach to science curriculum development.

According to Fensham (2002), Roberts' contributions were important for informing the meaning of scientific literacy and hence the role that these emphases would have in curriculum. Roberts envisioned that his seven emphases would each have a distinct contribution to the overall goals of science education, but would be neither prescriptive nor hierarchical. To over-emphasize any particular component of the science curriculum in all topic areas would most certainly overburden the curriculum and likely cause many of the emphases to have little effect at all. Apparently, as we will see in the next section, Roberts' intentions were misapplied in the overly ambitious outcomes and standards movement that characterizes Trajectory 3, where the inevitable compromises between curriculum developed by bureaucrats and the driving influences of academic science and the science education community led to a completely unrealistic size and scope for curriculum in Canadian science education.

By the late 1980s in Canada, STS in science education was gaining a level of theoretical importance that would eventually cause it to be a serious contender for underwriting the growing demand for curricula that had socio-scientific, socio-cultural, and perhaps even socio-political dimensions (Solomon & Aikenhead, 1994). For those who made the claim at that time that science education in Canada had overlooked some of the key recommendations of the Science Council of Canada (SCC, 1984c), an opportunity was made available through the science literacy movement to make an incursion into curriculum¹. Among the recommendations of the SCC, the

¹ The Science Council of Canada was dissolved in 1988 by the federal Conservative government under then Prime Minister, Brian Mulroney. No federal agency directly advised the Prime Minister on science and technology until 2004, when the federal Liberal government under Prime Minister Paul Martin appointed Dr. Arthur Carty, O.C. to head the newly-created Office of the National Science Advisor (ONSA). In 2007, when the Conservative government developed its *New Science Strategy*, the ONSA staff were not consulted. In 2008, the federal Conservative government under Prime Minister Steven Harper abolished the ONSA in favour of a new, arms-length

following would eventually become important voices in Canadian STS approaches to curriculum:

- Science education must include the study of how science, technology and society interact;
- Technology-oriented courses must be included in the secondary school curriculum;
- Students must be taught how Canadians have contributed to science and how science has affected Canadian society; and
- Science education must provide a more accurate view of the practice, uses and limitations of science (SCC, 1984c; p. 1).

Not unlike the manner in which earlier attempts to bridge the chasm between academic rationalist approaches to science education and a more humanistic and sociological inclination (e.g., Harvard Project Physics) faced fierce resistance from the strident voices of the science teachers and their academic counterparts, STS science in Canada in the 1980s was similarly on a path to tensions and difficulties gaining acceptance and ascendancy. A particularly notable example of how perilous it can be to obviate consultation with these two authoritative voices occurred in Alberta, Canada in the late 1980s and is recounted by Roberts (1988). In that instance, teacher development teams led by provincial bureaucrats proceeded with the development of a particularly forward-seeking STS curriculum but, in the end were blind-sided by the unexpected levels of opposition provided to the reforms by Alberta's university science community and a variety of vested political interests. This was an instance where setting aside protracted consultations with key stakeholders and underestimating the value of an on-going

Science, Technology and Innovation Council. As at 2014, the Minister of Industry reports to the Prime Minister on issues of science, technology and research.

deliberative process can undermine even the best intentions of curricularists. Curriculum development is indeed a process, but it is the products of that development and their perceived (not actual) implications for change that occupy the gaze of the stakeholders. Nonetheless, STS approaches in curriculum had attained a significant level of traction by the mid-1980s, and had particularly prominent international science educators such as Glen Aikenhead in Canada, Peter Fensham in Australia, Joan Solomon and Robin Millar in the UK, and Robert Yager in the United States (see Turner, 2008).

Coincident, and perhaps not an accident, is the coupling of STS science education with the re-emergent profile of scientific literacy in the early 1990s. This pairing, in my view, is the essence of the impetus behind the curriculum reforms characterizing Trajectory 2 and one of these (STS) could be considered as the theoretical and practical basis for a curriculum that orients itself principally toward the other outcome of developing scientifically *literate* individuals. There is perhaps a no more problematic term than “science literacy”, and its many definitions of what it is or what comprises go well beyond the scope of this paper, and have been extant since the late 1950s and still abound in the literature today (Hodson, 2002; 2007; Shamos, 1995).

By the time we reach the early 1990s, science education on Trajectory 2 was in full measure prepared to precipitate the most widespread science curriculum re-organization in three decades. There were significant drivers of this reform, principally the open letter to the American people by the National Commission on Excellence in Education (Gardiner et al., 1983) – *A Nation at Risk*. A flood of curriculum policy frameworks ensued from the American Association for the Advancement of Science in volumes such as *Science for All Americans* and *Benchmarks for Science Literacy* (AAAS, 1989; 1993) and the National Research Council’s *National Science*

Education Standards (Collins, 1995; NRC, 1996). In Canada, the Council of Ministers of Education Canada (CMEC, 1997) sponsored the first national framework for science education with the release of the *Common Framework of Science Learning Outcomes: Pan-Canadian Protocol for Collaboration on School Curriculum* and this provided STS science with a status on equal footing with the nature of science, science skills and processes, and scientific knowledge. In terms of its translation into curriculum among the Canadian provinces, this is where any sort of national consensus broke down and evanesced. By 2003, only four Canadian jurisdictions had re-organized science curriculum in accordance with the Pan-Canadian Framework – Manitoba, Ontario, Newfoundland & Labrador, and an Atlantic Provinces consortium comprising New Brunswick, Nova Scotia and Prince Edward Island. The province of Quebec did not participate in the development process from the outset, though the final framework was released in Canada's two official languages by constitutional mandate. What ensued for the jurisdictions that did reformulate curriculum based on the Pan-Canadian Framework was primarily a bureaucratic process of development that, for some, clearly demonstrated that what is intended in the process of national curriculum development is not always what transpires among the jurisdictions.

The root of Aikenhead's complaint that the process of development in Canada did not live up to the commonly held standards of research and scholarly input is an accurate assessment in light of the absence of deliberative inquiry facilitation as had become the hallmark for collaboration since the SCC study. When one looks at the position statements, policy documents, and background literature that ostensibly informed the development of the Pan-Canadian Framework it is evident that there was never any *intention* to follow a deliberative research approach to provide the framework with a firm set of up-to-date Canadian contexts and theoretical positions. The only possible way for a political organization such as the CMEC to

conduct the process of a consensus on science curriculum in Canada was to arrange for the following structure: (1) have the project staff comprised of select provincial representatives, few in number, who would tightly control the feedback to equally selective stakeholder groups; (2) have the project staff align themselves with certain extant international frameworks available at the time; (3) assemble as large a set of compromises as the Canadian landscape would accommodate (i.e., a framework simultaneously for everyone and yet no one in particular), and;(4) sidestep notable sources of expertise such as faculties of education and the scientific community. In other words, do not necessarily seek after a national curriculum at all which can then be translated into provincial curriculum, but a synthesis, a 'meta-curriculum', and commit the error foreshadowed by Roberts. That error was creating the conditions that attempt to satisfy all the emphases desired in curriculum in all areas of the curriculum, and attempt to do that simultaneously. So, to implicate the CMEC and the decision-making of multiple bureaucracies as not having accessed the best available research to inform the Pan-Canadian Framework, or not having lived up to standards of available scholarship, is actually an expected position (recall Connelly's oscillation model). Such a set of deliberative, consensus-building foundations were not intended by the CMEC process by virtue of its tight timelines for completion. According to observations on the CMEC process from a member of the project team of the Science Council of Canada study:

"[The] distinction concerns participants in any project. One of the key ideas in the Deliberative Inquiry model as it was used in the SCC study was that of stakeholders in science curriculum (drawing on Michael Connelly's work in that respect) but I also made a very significant distinction between two types of stakeholder, which I called 'insiders' and 'outsiders.' Insiders were defined as stakeholders with some decision-making role and so included people from the Ministry, school boards, schools, and the classroom teachers. Outsiders by contrast were

also stakeholders but whose roles gave them no direct authority to make decisions concerning science curriculum; these included employers, members of the science and technology communities, university/college faculty, parents, and of course students themselves. One of my observations was that insiders traditionally clung tightly to their control of the science curriculum (the Pan-Canadian Framework development was a classic in this regard) and so in the SCC study all deliberations involved equal numbers of outsiders and insiders.”

(G. Orpwood, pers. comm., December 7, 2012; used with permission)

It was both a phenomenon and a symptom of Trajectory 2 – Canada acceding to or aligning itself with international pressures to capture the essence of scientific literacy which was again in full flower. It was an illustration of a set of conditions that had set aside yet again the prospect for a uniquely Canadian context to science education. That call went out in the Symons’ Commission Report (1970s), the Background Studies of the Science Council of Canada study (1980s), the Council’s report itself (1984), and happens to appear in the bibliography of the Pan-Canadian Framework (CMEC, 1997).

Trajectory 3: Outcomes and Standards – the New Literacy of International Neo-Liberalism and Competitiveness

If Trajectory 1 was dominated by determining the structure and function of the disciplines of science, centralised curriculum and resource development, and science in the national interest; and if Trajectory 2 was characterised by the tensions created by the growing movement to foster scientific literacy and the implications and tensions created by the STS approach to curriculum, what portrayal do we have of a third trajectory in science education in Canada? Trajectory 3 has assumed certain elements and characteristics from the two previous trajectories, but has enough at its disposal to consider that the period of 2000-present to be

viewed roughly as the point of departure to a new pathway for Canadian science education – that of international collaboration and globalization (DeBoer, 2011; and commentary by Fensham, 2011)). Is there justification for this position? If there is a ‘genetics of curriculum’ then we can expect that certain ‘traits’ will be passed to future generations, some phenotypically evident while others end up being subsumed by the recessive forces in society and schooling.

Trajectory 3, in my view, maintains the following genetic factors from Trajectory 1:

- Science in the national interest, but now characterized by international competitiveness and globalizing forces in the wake of the collapse of the Soviet Bloc (see, for instance, Clinton & Gore (1994); Krige, (2000); Neal, Smith & McCormick, (2008));
- Centralised development of a knowledge dominant curriculum with close monitoring of approved learning resources; and
- Significant attention devoted to the assessment of individual student achievement.

Trajectory 3 also maintains the following genetic factors from Trajectory 2:

- Teacher dissatisfaction with centralised and prescriptive curriculum;
- The tensions over differentiated instruction (an evolution from streaming of science students to an attempt at differentiating at the whole-class level with de-streaming); and
- The continuing struggle for acceptance of the STS approach (VISION II) among science educators and external stakeholders; that is, the tension between the structured disciplines approach and social/humanistic aspects of science education remains.

What, then, are some of the distinguishing factors that argue for the most recent decade or so as being an entirely distinct trajectory for science education in Canada? I would point to two such distinguishing features: 1) Science education as now being in the interests of the private sector and its globalizing economic agenda (neo-liberalism) such that formerly national interests such as international scientific prestige have taken on a new form related more to economic well-

being as related directly to its educational success (i.e., international competitiveness and rankings on mass-scale assessments); and 2) the advent of effects and influences given over to large-scale international assessments. These now include the *Programme for International Student Assessment (PISA)*; similar Canadian large-scale measures such as the former *School Achievement Indicators Program (SAIP)* which was more content oriented and its newer set of measures that are more context-oriented in the *Pan-Canadian Assessment Program (PCAP)*.

In terms of the first of these features, at the time of the outset of Trajectory 3, William A. Reid (1998) commented in the *Journal of Curriculum Studies* that curriculum was now at an end – but not in the same sense as “the field of curriculum is moribund” as Schwab (1969) put it 20 years earlier. For Reid, a symptom of that ‘end’ was explicated by the realization that multi-national corporations were being invited by government authorities to rescue from ruin underperforming schools in the United States. Moreover, this was to occur in areas of large American cities where standards were considered low, there was no political voice to advocate against the move, and this would happen with or without the cooperation of local education authorities (see, for instance Byrnes (2009) for the examples of Cincinnati, Ohio and Philadelphia, Pennsylvania). It is now occurring with science education with the *Next Generation Science Standards* currently under development by the National Academies of Sciences, the National Research Council, and supported by the unprecedented international comparisons conducted in 2010 by the incorporated non-profit organization known as Achieve, Inc. (National Science Teachers’ Association (NSTA), 2012; NRC, 2012; Achieve, Inc. 2010). Achieve was organised in 1996 from a bipartisan group of U.S. state governors and corporate leaders whose mission is to dedicate itself to supporting standards-based education reform. Its board of directors includes four state governors and four former CEOs of major financial and electronics

corporations. Achieve (2010) conducted a review of the science content standards of 10 countries in order to look for commonalities that were “worthy of emulation”. Of the original 10 countries whose standards were reviewed (Canada, Chinese Taipei, England, Finland, Hong Kong, Hungary, Ireland, Japan, Singapore, and South Korea) 5 were ultimately chosen (Canada, England, Hong Kong, Japan, and Singapore) for more in-depth analysis by content experts. According to the Achieve study (p.40), the content experts were tasked with determining the characteristics of each country’s curriculum standards in these six areas: *coherence, focus, rigour, progression, specificity, and clarity and accessibility*.

To paraphrase George E. DeBoer as he opened his 2011 article, the following provocative question arises: “Would it be productive to begin a conversation about creating common *international standards* and accompanying assessments....as citizens of the world.” (DeBoer, 2011; p. 568; *italics* my own). Such a view is the very essence of the globalized science curriculum. DeBoer closes his discussion with eight considerations related to the potential for developing an international set of science education standards. One in particular has a close connection to the proposed study here because it recognises the legitimate national interest: “Any standards document, whether written in terms of integrated student competencies or in terms of discrete knowledge and skill statements, must reflect the results of research in science education in that country as well as that country’s traditions and values regarding education.” (p. 586). Fensham (2011), in a commentary to DeBoer, outlined a disconnect between many of the potential positive aspects of international collaboration in science education research and what practically occurs among bureaucracies of education. His chief criticism was that “there is a clear tendency in a number of countries for the bureaucracy of education to supersede science and science education experts in the ultimate determination of the science curriculum....[and] by no

means is it consistently directed” (p. 707). The phenomenon of national curricula evolving in countries having traditionally provincial (or state) control over education is, for Fensham “the decline of expertise and rise of bureaucratise” (2009; 2011; 2012).

The voluntary public consultations conducted in 2012 through to early 2013 by Achieve intended to produce and develop an entirely new set of outcomes, indicators, clarification statements, and standards for K-12 science education in the U.S. The foundational document framework upon which the new standards were explicated was the *Framework for K-12 Science Education* developed by the National Research Council (NRC, 2012), and has now completed that process with a release of the final-form *Next Generation Science Standards* (Achieve, Inc., 2013). The principal rationale for this new round of standards development that has been offered is simply this: fifteen years have passed since the science literacy standards of the early 1990s and so the time is right for a change and to refresh. That seems more of a cursory political statement than a purposeful statement of the rationale to examine the foundations of science curriculum.

Without a full and comprehensive, research-based analysis of what occurred in the period of Trajectory 2 there appears to be little in the way of a defensible rationale for moving forward, and doing so at the expense of the nature of science and the history of science (both are recommended for removal, with engineering concepts put in their place) (NSTA, 2012). The criteria of the core ideas presented in the *Next Generation Science Standards* do, however, appear rather familiar:

- Have broad importance across multiple sciences or engineering disciplines;
- Be a key organizing principle of a single discipline;
- Provide a key tool for understanding or investigating more complex ideas and solving problems;

- Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge; and
- Be teachable and learnable over multiple grades at increasing levels of depth and sophistication (i.e., the spiral curriculum) (Achieve, Inc., 2013).

The second feature of Trajectory 3 - large-scale periodic international assessments in science (in addition to mathematics and the literary disciplines) bring a whole new set of pressures to the curriculum landscape, not the least of which is a plethora of performance indicators (Estevez, 2011). Science educators at almost every level have become necessarily swept up into the need to cross-reference their classroom practices and professional independence with student performance as gauged by external measures. Even if these are done with random sampling procedures that are national in reach, there is a certain residual pressure at the local level to feel as though one is making a contribution to a successful status in very public pronouncements of achievement. To cite an example from Canada and the experiences with PISA / PCAP, even though the results are samples from representative national populations, results are reported *provincially and linguistically* in accordance with Canada's provincial jurisdiction over education systems and its two official languages. Hence, such large-scale assessments of student achievement in science in Canada may – inadvertently and with some expedience – ignite inter-jurisdictional competitiveness or perhaps worse, taking aim at provincial science curriculum as the culprit if results are unsatisfactory at the political level. Orpwood & Barnett (1997), upon examining curriculum frameworks from Australia, New Zealand, the U.K. and the United States maintained that a “curriculum framework is a necessary but not a sufficient condition for quality teaching and learning. No national framework or curriculum policy, however well developed, can function as a direct instrument to effect pupils’

learning – the failure of past attempts [at doing so] are surely evidence of this. [at] the same time, the education and support of teachers is still seen as a footnote to the development of curriculum.” (p. 347). Notwithstanding their arguments, experience often tells us that a popular means by which governments and bureaucracies respond to less than satisfactory outcomes of student achievement is to revise curriculum.

At this point, I wish to explore in sufficient detail the most recent example of the development of a national consensus framework in Canada for science education. This is provided for at least two reasons: 1) it is a type example, according to certain reviewers, of an almost exclusively bureaucratic approach to the development of curriculum, and; 2) it echoes Tomkins’ assertions that there is a tradition in the matter of curriculum development in Canada to claim that the outcome of the process is Canadian while at the same time it is clear enough that the documents which inform the process are not Canadian in origin.

The Pan-Canadian Protocol for Collaboration on School Curriculum

All foundational curriculum documents that have held significant influence and sway in Canadian science curriculum reform such as *Science for All Americans* (AAAS, 1999; Rutherford & Ahlgren, 1989), *Benchmarks for Science Literacy* (AAAS, 1993), the *National Science Education Standards* (NRC, 1996; 2012) and others have, arguably, paid plenty of attention to the inputs from a wide array of educational stakeholders. Not all stakeholder influences, however, are equal. For example, we have observed previously that in the post-*Sputnik* era, the science curriculum took a decided trajectory away from industrial applications and quaint examinations of the biosphere (e.g., “nature studies”) to a sophisticated, abstract, and intellectually challenging emphasis to areas such as the structure of the disciplines, the nature of

science, prescriptive scientific inquiry, and the processes of science learning for the sake of international stature.

The immense funding provided by the National Science Foundation in the United States during the 1960s and the unprecedented influence of the academic scientific community on curriculum as a result was no accident. This historical example portrays what can happen when the scope of interests for society is too narrow to eventually see relevance in curriculum to broader sets of experiences. Alternatively, the struggle for STS in science curriculum in Canada on Trajectory 2 is a tale of stubborn resistance to science educators who have deep ideological and epistemological commitments to academic rationalism and often see alternative perspectives and ideologies in curriculum as distractions, superfluous, or to use the vernacular of choice, “watering down the curriculum”. In the case of the present reform in science education characterized by outcomes and standards (Trajectory 3), we have a curious situation at hand in terms of stakeholder voices in Canada. There is essentially only one, and that is the Council of Ministers of Education, Canada which has imbued the curriculum of many Canadian jurisdictions with the contents from a single, national framework document – the *Common Framework* (CMEC, 1997) .

The review by Weinrib and Jones (2013) correctly notes that “it (the *Common Framework*) represents the only major document put forward at the national level in Canada regarding science curricula in the last 20 years.” (p. 20). Their perspective claims that the *Common Framework* was built on the foundations of earlier initiatives and documents from the Canadian landscape such as the study conducted in the 1980s by the Science Council of Canada, the 1993 CMEC Victoria Declaration providing direction to national curriculum harmonization among Canada’s provinces and territories (CMEC, 1993). The bibliography of the *Common*

Framework seems to indicate that only the SCC study held influence from a science education policy perspective, and all other contributors were minor voices as suggested reading. Aikenhead (1999) contended that even the SCC study was insufficiently sought as a national curricular foundation, and that experts in the field in Canada were not adequately consulted as the *Common Framework* took shape. Though the *Common Framework* does provide a varied bibliography of source documents that supposedly informed the process of its development and laid the foundations for its theoretical stance(s), the document is very silent on how the supportive literature provided the actual voices to Canadian science educators or to just where the literature base is actualized within the framework. If one reads the document closely (or more likely in a cursory fashion), it could be casually concluded that in Canada we have had for the last 20 years in Canada a national science curriculum framework that is void of a theoretical set of commitments, guiding assumptions, expert input, and a truly Canadian context.

The *Common Framework* echoed earlier calls for the development of increased literacy in science for all Canadians. The concept of scientific literacy was, at the time of the assembly of the *Common Framework*, a core concept that was simultaneously ill-defined, problematic (Shamos, 1995), and perhaps was even considered moribund 15 years earlier by Canadian researchers (e.g., Roberts, 1983). Even now, the concept is being re-oriented and expanded toward servicing a re-conceptualization of the aims of science education in the “knowledge economy” (Liu, 2013). Milford, Jagger, Yore & Anderson (2010) and Yore (2011), in their respective analyses of the impacts and effects of the *Common Framework* as it was translated into curriculum, noted that the concept of science literacy was so generalised and vague that it really lacked any sort of effective operational definition, and that it was difficult to ascertain at the provincial level just how it was to be realized through curriculum, instruction, and learning.

With respect to science literacy, Milford *et al.* (2010) provide a response from an anonymous survey participant who put this perspective on the relationship between science literacy and its role in the *Common Framework*:

“Here in Canada, the CMEC desire to have a national standard in science seemed to align with the goals that were already underway in the USA. The NRC Standards, for instance, that has driven much of state curriculum standards south of the border was an important driver in keeping all of us in Canada “driven” toward the illusory goal of science literacy. I say “illusory” because the term scientific literacy became a sort of slogan, or “ism” that was simultaneously ill-defined and central to the architecture of science curriculum (quoted in Milford *et al.* (2010); p. 378; emphasis my own).

Weinrib and Jones (2013) have provided encouragement to undertake this study by stating that “the [*Common Framework*] suffers from having an ‘expiry date’; the document is extremely out-dated and does not reflect the vast STS developments that have occurred over the past 15 years, particularly the development of ICT and the ubiquity of personal technological devices. As such, the *Common Framework* is something of an antiquity already despite the fact that it remains the most recent national policy document on science curriculum at both the primary and secondary levels [in Canada].” (p. 21). Milford *et al.* (2010) made mention of the publication date issue a few years earlier with what they have called a “best before date” problem with the *Common Framework*. At the time of their review the *Common Framework* was 12 years old, and was considered as:

“...[past] the limit of the curriculum revision cycle. There appears to be some support among those who were originally involved in the initial Pan-Canadian document and others who currently work with it for such an undertaking [document refresh]. The renewal of the Framework would accomplish the reinforcement and refinement of its central focus and foundations (the literacy component of scientific literacy, nature of science as inquiry, technology as design, argument in science, balance across STSE/knowledge/skills/attitudes, etc.) and reassertion and inclusion of contemporary topics (water quality, climate sciences, etc.), capture emerging trends, issues and topics not possible in the original (traditional ecological knowledge, acculturation into a science/technology discourse community, etc.) and build leadership capacity within the science teaching and science education communities [in Canada]. There is significant need to renew leadership and build advocacy for science education that could be partially addressed by participation in the deliberations associated with the renewal of the Framework.” (p. 380).

This chapter was intended to provide a particularly Canadian emphasis to the literature review for this study. It began with identifying a starting point in the 1950s which was not entirely arbitrary. The choice of 1957 as our starting point is not in any way to indicate that the success of *Sputnik 1* is to be identified as the starting point for a massive effort to reform science curriculum in Canada, or elsewhere. It provides a connection for the reader – an historical benchmark - which still lives in the minds and memories of many. That year is to be viewed as one which characterised, almost by definition, the opening of the modern era of science curriculum focus among Canadians and their geopolitical allies. The three trajectories of developments in science education discussed in this chapter are considered to have fluid boundaries and are developed here to provide context to what has come before and what could become future ‘trajectories’. It is further noted that, in my opinion, certain genetic characteristics of one trajectory can be found in the others. This view would be consistent with Connelly’s notion of oscillations in curriculum, at times parallel. To close, four recent developments, any one of which (or in combination) could provide the confluence of conditions, threats/opportunities, and/or the political/pedagogical environment for a reconceptualization of the foundations of Canadian science curriculum. These could include (not in any order indicating significance): (1) the December, 2013 release of the OECD 2012 PISA student assessment

results for Canada and jurisdictional reactions to it; (2) the September, 2014 release of the PCAP 2013 student assessment results for Canada and attendant jurisdictional reactions to it; (3) a wider recognition and acceptance of the *Pan-Canadian Common Framework* as antiquated, and; (3) the degree of acceptance of, or rejection of, the *Next Generation Science Standards (NGSS)* currently ascendant in U.S. state education systems.

The next section, also a literature review, is intentionally complementary to this chapter as it particular focuses on the Delphi approach as a methodology. In my view, the dissertation is a place where a more extensive treatment of methodological decisions is warranted though it may seem irregular in this instance. Space limitations among peer-reviewed publications force a gloss of Delphi. My hope is that a second literature section will provide a deeper sense of understanding of the Delphi which is all too rare in the extant literature.

Chapter 3: Literature Review II - The Delphi Method

Delphi Methodology: The Conceptual Framework and Considerations for other Research Designs

In his follow-up to the 1984 Science Council of Canada (SCC) study of science education in Canada, Graham Orpwood published a review of the inquiry procedures used in that study and claimed that consultations with stakeholders allows curriculum policy-making to go more smoothly (Orpwood, 1985). He claimed that the SCC project was essentially a means to change policy and practices in science education in Canada, and was “aimed to challenge the wills and well as the minds of those participating”. In addition, Orpwood states that “one of the by-products of major policy reviews is that the unique situation faced by each separate national study has resulted in the development of new methodological approaches or strategies”. I was intrigued by the potential for ‘new methodological approaches or strategies’ options since the study undertaken here was national in scope, would naturally include opinion-making on current practices and curriculum policy, and could be considered as a chance for an approach to be taken which had not been attempted before. Hence, upon noting the success with which a new inquiry technique had borne fruit in the SCC study, it was natural to give consideration to modifying the classical Delphi technique and providing a provisional sort of field validation for this study.

The large-scale study conducted by the SCC in the early 1980s made explicit use of deliberative inquiry techniques which had been refined just a few years earlier by Orpwood himself. A particular form of the deliberative inquiry methodology had been developed theoretically by Orpwood in his doctoral dissertation and then applied for the first time in the 1984 SCC study into Canadian science education (Orpwood, 1981). That study was conducted

among a wide array of stakeholders, and it was accepted by the participants themselves that this was the best manner in which a sensible and representative model for Canadian science education policy would be achieved (Aikenhead, 1980; Orpwood, 1985; SCC, 1994a). In a look backward at the technique, Aikenhead, stated that “the most elaborate, theory-based, consultative methodology that can applied to analyse curriculum policy is *deliberative inquiry*.” (2009; p. 51; *italics* in original). Aikenhead suggested that the structure and dialogue among stakeholders implied by deliberative inquiry is ideally suited to Canadian ways of doing things and making decisions. He did not elaborate on this point and so we are left to conjecture that certain other approaches could be deemed “un-Canadian”. The process – if it were utilized for an inquiry into the current state of curriculum – would be expected to take the form of an emergent consensus between those who are the external stakeholders in education and those who either are (or feel that they are) responsible for the means and ends of curriculum policy. This latter group, whom Orpwood preferred to name as the “insiders”, would be exemplified in school administration, teacher development teams, or provincial departments of education and elected officials (Orpwood, 1985).

The SCC research project was differentiated across three domains that were considered the basis for the eventual detailed methodology used in the study. These domains, for the purposes here of inquiry into Canadian science curriculum, can be adapted to the following: (1) science curricula as equivalent to policy; (2) needs assessment and the discovery of foundations, goals, or objectives, and; (3) the interplay of stakeholders and voices in laying the foundations for the science curriculum, for teaching, and for learning.

As a matter of historical and methodological note, the SCC study conducted by Orpwood and associates occurred over the span of years 1981 to 1984 (SCC, 1984a; 1984b; 1984c;

Orpwood, 1985; Orpwood & Souque, 1984; 1985). Its work essentially introduced a form of the deliberative inquiry methodology as a means of policy inquiry into the state of science education in Canada. Deliberative inquiry in this form is a structured, dialogic conversation that occurs face-to-face among the stakeholders who are represented equitably and in pairs. That is, for example, two science teachers, two school administrators, two representatives of an education ministry, and so on. The technique is lengthy, expensive, and exhaustive. It involves discussion of priorities, revision and re-examination of priorities, the reading of the relevant research, and making commitments to the prospect of implementing what is eventually agreed upon. Conducting a deliberative inquiry has, since its inception in the late 1970s, been viewed by its supporters as an effective way in which policy positions can be reasoned out among interested groups. It is a protracted and meticulous process that requires participants to have access to regular, face-to-face sessions facilitated by the researcher.

The SCC study was intended as a background study and so was not intended to lead to federal policy statements or specific projects in Canadian provinces and territories. It was an opportune period to apply new methods of inquiry into curriculum policy that had become emergent just a few years earlier in the deliberative inquiry models developed by Reid (1979; 1981). It is noteworthy in terms of context that Orpwood's doctoral dissertation (under the supervision of Douglas Roberts at the Ontario Institute for Studies in Education (OISE) at the University of Toronto) was completed the same year that Reid spoke publicly at the annual meeting of the American Educational Research Association (AERA) on the deliberative approach to the study of curriculum. One could have speculated at the time that there were convergent and unique conditions coming about in Canada for a serious look into the status of science education in Canadian schools. Perhaps Orpwood himself attended that AERA meeting

as a newly-minted PhD in curriculum policy. He was certainly in Montreal, Québec, attending the AERA conference in 1983 (Orpwood, 1983a). And so, while still a doctoral candidate, he had already become involved with the research team assembled in 1979-1980 to conduct the SCC's *Science and Education Study* during its critical years 1980-1984 (SCC, 1984a).

When interviewed for the research presented in this study, Orpwood – who at the time was the Science Advisor to the Science Council of Canada and the Project Officer for the Science and Education Study – provides clear insights into the experience of deliberative inquiry in a national setting. It is worthwhile to present one of his recollections here:

“What I was absolutely trying to do in the SCC study was to see if we could develop - from our multiple perspectives as represented by the discussion papers – the kinds of consensus which could move us forward in certain directions - 12 times. Every province and territory. And what was remarkable was that I found that when you do this 12 times over, the degree to which individual provinces were the same was vastly greater than their differences. Some 20% of the discussions which took place in the deliberative conferences were around local issues, issues which were particular to Manitoba, to Alberta, to Quebec and so on. About 80% of what took place at those meetings were in common actually... the same as every other province and so when the Science Council of Canada was able to take their 80% and express it in the form of its final report, we had people in every province and territory looking at that report and saying “that’s exactly what we told them!” Everyone had a sense in which everybody said “yes, this is where we should begin” and it was that sense of “yes, this is where we should be going” that caused everybody to feel so positive about Science Council report; and they had already told us that separately in each province.” Orpwood, personal communication, May 1, 2014)

Initially, some variant of deliberative inquiry was considered as a methodology for the proposed study here by virtue of its past applications to inquiry into public policy with respect to

Canadian science education. It is also important to identify that both the Nominal Group Technique (NGT) and the Program Planning Model (PPM) were also considerations – but secondary ones to deliberative inquiry - as these too involve semi-structured to very structured processes for group decision-making. Originally developed by André Delbecq and Andrew Van de Ven in the late 1960s, NGT and PPM were targeted at management decision-making in organizations. For the purposes of this discussion, the two techniques (NGT and PPM) are considered analogous methodologies but with their own distinguishing characteristics.

The PPM approach was customarily applied to program development, and involved five phases of activity with both external resource contributors and the experts from within the organization. It is actually quite reminiscent of the traditional “scientific method” of inquiry. The entire process of PPM/NGT can be summarised as follows (Delbecq and Van de Ven, 1971), with the addition of my adaptations to the development of educational policy and programming (e.g., curriculum inquiry):

Phase 1: Problem Exploration

- Involvement of end-user clients and senior-level management
- Teachers, teacher-educators, senior bureaucrats

Phase 2: Knowledge Exploration

- Involvement of external expertise (often scientific) and internal and external specialists
- Academic researchers, subject-area curriculum consultants

Phase 3: Priority Development

- Involvement of key administrators and fiscal resource controllers
- School district superintendents; provincial Treasury Board

Phase 4: Program Development

- Involvement of front-line administrators and specialists
- Principals of schools; school district science education coordinators; technical specialists in program delivery

Phase 5: Program Evaluation

- Involvement of end-user clients, staff, and administration
- Teachers, teacher aides, assessment specialists

The NGT includes a four-step process, which are often included in the first three phases of the PPM. As outlined in Delbecq and Van de Ven (1971), these steps are:

- 1) A process wherein silent written ideas are generated by the participants;
- 2) A round-robin process for the sharing of ideas and for the facilitator(s) to record each idea;
- 3) A discussion among the group members to allow for clarification of each of the recorded ideas, and;
- 4) Each idea is then voted upon (in secret) and subsequently weighted numerically.

Both the PPM and NGT techniques involve having the participants synchronously located (time and place, and face-to-face) with the interventions of a facilitator. For this study – which is to involve a national-level panel of experts – it was deemed not feasible to use such techniques.

Landeta, Barrutia and Lertxundi (2011) asked the question, “What is the best way of extracting and processing the information possessed by a set of professionals concerning a problem or phenomenon?” (p. 1629). The synthetic methodology that helped to answer this question was assembled as an amalgam of three well-known qualitative techniques (Focus Groups (FG), NGT, and Delphi) into a hybrid technique that, in their belief, would “harmonise their potentialities and reduce their limitations through application in real contexts with experts who are professionals in their respective activities” (p. 1629). Their model methodology involved the structured face-to-face, moderated discussion groups around a pre-defined subject characteristic of FG; the silent responses and idea-making with eventual anonymous assessment

and exposition of the NGT, and; the iterative processes, anonymity, controlled feedback and statistical group response offered by the Delphi method. Taken together and adjusted to capitalize on the strengths inherent in each approach, this “hybrid Delphi” methodology of Landeta *et al.* intends, in principle, to mitigate or eliminate altogether the shortcomings of any one of the three. These authors readily admit that their technique was not novel to research methodology nor to the literature theoretically – the basis for the hybrid model comprising FG, NGT and Delphi first appeared in Van de Ven & Delbecq (1974) - but was applied *in toto* in circumstances that had not yet been field validated (e.g., developing an assessment model for competencies in community nursing).

This model initially appeared very attractive for this study, but with extensive modifications necessary to fit the nature of the research. For example, certain of the characteristics of both PPM and NGT would be included in the online questionnaire experiences of participants in the Delphi itself (e.g., inclusion of external expertise (often scientific) and internal and external specialists, a process wherein silent written ideas are generated by the participants, and each idea is voted upon and subsequently weighted numerically). The focus group component would be set aside in favour of after-the-Delphi semi-structured interviews taking their place. The interviews would be expected to be few in number and strategic in order to provide *representative views* of significant themes emerging from the study.

Landeta *et al.* (2011) concluded that the outcomes of their “hybridized” process must be considered as a “holistic whole” with the contributions of all three component techniques involved in the interpretation and understandings coming through in the results. Hence, they claimed that it is not a modified Delphi technique but a true hybrid and warranted a new name – the hybrid Delphi. To provide an example, Landeta *et al.* identify a study conducted with

associates working in the contentious Basque region of Spain who characterized and distinguished the hybrid Delphi for its “joint consideration of the needs of the investigator and also those of the experts who acted in professional contexts in order to improve the effectiveness of preceding techniques in achieving the scientific and social objectives of the study” (p. 1637).

In my study, it became apparent that any “face-to-face” stage (the interviews) would be conducted *after* the anonymous online components of the Delphi were completed and that these interviews would be conducted at a distance through electronic means. Initially, the research proposal intended to conduct interviews at the outset of the study (prior to Round 1) and at intermediary points between subsequent rounds of the Delphi. The intention of this decision was to avoid the prospect of a small subset of the expert panel controlling what was fed into the Round 1 questionnaire and subsequent rounds. I had hoped that this earlier, episodic “face-to-face” stage would have mirrored the “background paper” approach used in the SCC study, but I soon recognized the importance of allowing the emergence of the themes guiding further deliberations in the Delphi to come about through natural means and not by way of a preconceived interventions (e.g. conducting semi-structured interviews prior to the Delphi).. What was initially to be a new variant of the hybrid Delphi methodology of Landeta *et al.* was eventually abandoned in favour of what is described more appropriately as a modified classical Delphi of the sort advocated by Linstone and Turoff, (2002).

According to Harris (in Short, 1991, p. 285), “deliberative inquiry is a policy and action-oriented form of inquiry which links the interrelated tasks of doing practical work in curriculum activity and formal curriculum inquiry”. It is a model of inquiry that owes much of its development and applications to curriculum inquiry to Reid (1979; 1981) and has deeper roots in the aspirations for curriculum theory and design of J.J. Schwab (see Schwab, 1969; 1971; 1973).

As attractive as this form of ‘grassroots’ and ‘top-down’ method of inquiry might be for curriculum policy (it has been used, for instance, as a sort of conversational bridge between theory and practice), it has both intended and unintended consequences. One of the possible intended consequences is that stakeholders in the deliberative process may not actually have a voice in the outcome. It is possible, and perhaps probable, that certain individuals were brought to the policy inquiry process principally as observers in an *ad hoc* selection process. In the extreme, these individuals or interest groups were perhaps naively self-deceived that they were actual policy-makers when their role was intended to be curriculum policy *implementers*. Among the prevalent unintended consequences of establishing a curricular roundtable of stakeholders is the effect upon the deliberations of one or two dominant and/or persuasive voices.

On occasion in this researcher’s experience where teacher-dominated curriculum development teams are assembled, it was difficult for such a group to avoid “coat tail” effects, appeals to recognized authority figures, or the inability to converse in a vigorous fashion about the research base with academic science education researchers. In addition, having strong or strident voices in face-to-face settings can lead to dysfunction as vested interests compete for policy formulation in curriculum. Many of these unintended consequences or obstacles could be overcome if the expert panel’s voices and presence were to be kept hidden from view in terms of the faces present, while still providing exceptional access to the ideas, points of view, criticisms, observations, and opinions of the expert panel. Consequently, since the scope of this study here does not include a comprehensive analysis of the present state of science curriculum in Canada nor affords the opportunity for disparate groups (both ideologically and geographically) to assemble face-to-face, there was an opportunity to adopt a new methodological approach or strategy as mentioned earlier. Ideally, certain attributes of the deliberative inquiry methodology

were considered as potential adaptations of the traditional Delphi method of Linstone and Turoff (2002) and thereby bring together certain of the strengths of both methods into a sort of mixed-methods Delphi technique. Provisionally, at the time of the research proposal, the process was referred to as “deliberative inquiry through Delphi”. It would have set about, for instance, soliciting candid views from an expert community in Canadian science education while simultaneously avoiding some of the pitfalls of the deliberative inquiry approach and other techniques involving face-to-face interactions. The next section will provide a synoptic-style history of the Delphi method. This is considered important for the reader in order to avoid the prospect of extensive external access to what has now become a large volume of literature devoted to the technique. In my experience with the literature in studies using the Delphi technique there is often no more than scant attention given in this regard. Therefore, the treatment here is intentional and not considered outside of the purposes of the research.

The Delphi Method – History, Threats, and Opportunities

The Delphi method was originally developed in the late 1950s by researchers at the RAND Corporation in California, but became 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 the 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). The project came to be known as “DELPHI Project” as an appeal to,

and as allegory of, field generals in Hellenistic times consulting the Oracle at Delphi to ascertain the outcome of their future military campaigns.

According to a retrospective on Delphi by Turoff and Hiltz (1996), the term ‘Delphi’ was never a name that the progenitors of the research technique – Dalkey and Helmer-Hirschberg – were particularly fond of. They described its origins this way:

“Since many of the early Delphi studies focused on utilizing the technique to make forecasts of future occurrences, the name was first applied by some others at the RAND Corporation as a joke. However, the name stuck. The resulting image – of a priestess (the *Pythia*) sitting scantily clad on a stool over a crack in the earth, inhaling sulphurous fumes, and making vague and jumbled statements about the future with many possible interpretations – did not exactly inspire confidence in the Delphi Method” (p. 56)

About a decade after the RAND Corporation permitted the release of the technique, Harold Linstone and Murray Turoff (1975) published *The Delphi Method: Techniques and Applications* which even today is considered the standard backgrounder among researchers who develop modifications to the original Delphi approach (Linstone & Turoff, 1975; 2002). 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. They first encountered Delphi in about 1968, when Harold Linstone was preparing the first issue as editor of the new journal *Technological Forecasting and Social Change (TFSC)* and Murray Turoff worked in the Office of Emergency Preparedness. This collaboration was to continue until the present, with *TFSC* still the leading international publication for futures research. In their summary observations regarding the future of Delphi, Linstone and Turoff (2011) 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. However, given the history of this field [forecasting and social change] it is unlikely these systems will be referred to as Delphi systems. One would hope those that develop these systems will pay attention to what we already know about large-scale collaboration and will not be relearning and stumbling over the same problems many of us have had to deal with in the past.” (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 a;b;c), where rapidly changing events are occurring or are considered to be imminent (Patton, 1990; 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 judgements of an expert community: a) to document and assess those judgements 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 verbalised 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.

There exist in the Delphi study literature (e.g., see the extensive bibliography contained in Linstone and Turoff, 2002) three distinct types of methods. These are the classical, the decision-making, and the policy Delphi respectively. Franklin and Hart (2007) indicate that the

classical Delphi method “functions as a forum for establishing facts about a specific situation or topic; the decision-making Delphi is used to encourage collaborative decision-making, and idea generation about a topic is the purpose of the policy Delphi method.” (p. 238). These authors further state that the generally accepted definition of the policy Delphi approach implies three important components observable in a policy Delphi *study*: a) there exists a researcher-selected sample of the expert community; b) the expert opinion of the group is sampled through an iterative process of administering a sequential set of questionnaires, and; c) the data from each questionnaire is summarized both qualitatively and semi-quantitatively to be then fed back into the expert community for further comments. Murry and Hammons (1995) and other adherents to the Delphi method agree that the attractiveness of the process is in postulating that group decisions are more reliable than those taken by an individual, and that the informed, intuitive opinions of the expert community tend to be more objective than those made by the individual.

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 statistical analyses (Cochran, 1983). Murry and Hammons (1995) identify four principal advantages of the Delphi approach in securing the opinions of experts. As these are enumerated

here, it is instructive to bear in mind some of the difficulties outlined earlier in the more deliberative methodologies:

- 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 judgement can be distorted by group pressures to conform (p. 82)

Uhl (1983) cautions that the popularity of the Delphi method should not allow for the technique itself to dictate the course of the research nor determine the problem under study. In his view, the Delphi technique may be warranted as a methodology if some or all of the following apply to the situation: 1) the resolution of a problem can be facilitated by the collective

judgements of one or more expert groups; 2) those groups providing judgement are unlikely to communicate adequately, effectively, or collegially without an intervening process; 3) the solution is more likely to be accepted if more people are involved in its development than would be possible in a face-to-face set of meetings; 4) frequent meetings of the group are not practical because of time, distance, and other constraints; and 5) one or more of the participants (or participant groups) have a reputation for being more dominant than another. (p. 84).

Then there are the various mythologies and misrepresentations of the Delphi process that have, on occasion, allegedly led many entry-level researchers to conduct less than adequate studies using the technique at the dissertation level (Rieger, 1986). Rieger notes that too few doctoral dissertations using Delphi techniques have paid attention to Sackman's historic RAND Corporation memorandum paper that was simultaneously a classic treatise and a devastating critique of Delphi on two fronts: these being "questionable application of the technique with respect to established professional standards for opinion questionnaires as stated in the norms and standards of the American Psychological Association (APA)" and whether the technique had "scientific validity with respect to engaging human subjects" (Sackman, 1974b; p. iii). In his systematic and lengthy critique, Sackman ends his set of recommendations with a clear direction that "the conventional Delphi [should] be dropped from institutional, corporate, and government use until its principles, methods, and fundamental applications can be experimentally established as scientifically tenable." (p.70). In defense of the nascent Delphi technique at that point in its history, Rieger (1986) makes reference to the context of the times in which Sackman was making his case. He pointed out that the situation as it was then was revealing "the operation of a Kuhnian paradigm [in the social sciences] and may be viewed as part of the wider debate operating at the time about quantitative versus qualitative research methods, but [the debate]

was not clearly identified as such at the time.” (p.196). That is to say, Sackman’s focus on established psychometric techniques seemed to accuse the Delphi method as scientifically suspect on the one hand, and its use of questionnaire construction on the other hand demanded that researchers pay heed to what was to be found in any conventional research paradigm – including proper population sampling, piloting procedures, questionnaire validity, and reliability concerns addressed. An effective Delphi inquiry relies somewhat on both of these “hands” to know what the other is doing.

In his overview of methodological considerations in the Delphi process, Ziglio (1996) makes reference to the “meticulously researched article” of Goldschmidt (1975) which dismantled most of Sackman’s concerns. Goldschmidt admitted that many Delphi studies were poorly constructed, contained questionnaires that were not pre-tested or contained ambiguous questions; but on balance warned that it was a fundamental mistake to equate the application of the Delphi method with the method itself. Linstone (2002; [1975]), in his dual role as one of the notable defendants of the Delphi method and one to highlight notable cautions in its use, took issue with Sackman’s claim that Delphi was somehow unscientific by countering that his (Sackman’s) view of the nature of scientific inquiry was too parochial:

“Science to Sackman means psychometrically trained social scientists. His tradition-bound attitude is not uncommon; it is in the same vein as the illusion that science is ‘objective’, that only Lockean or Leibnizian inquiring systems are legitimate, and subjective or Bayesian probability is heretical. Orthodoxy faced with new paradigms often responds with sweeping condemnations and unwitting distortions.” (p. 559; quoted in Ziglio (1996); p. 13)

Ziglio (1996) closes his overview chapter with eight detailed recommendations for researchers undertaking Delphi studies. Of these, the following four stood out for the purposes of constructing an appropriate Delphi experience in this study:

- 1) The Delphi technique attempts to draw on a wide reservoir of knowledge, experience and expertise in a *systematic manner* instead of relying on *ad hoc* communications with selected individuals;
- 2) The Delphi method should be used when the primary source of information sought is *informed judgement*. In other words, where there is uncertainty on both the nature of the problem under investigation and the possible policy measures for addressing it effectively and efficiently;
- 3) There are many instances in social policy where decisions would require knowledge which is not readily available [from traditional sources such as the literature base]. In these situations there is a reliance upon the *opinion of experts*. A challenge is how to secure such expert opinion, and how to reconcile different opinions about the subject matter – Delphi processes challenge the investigator; and
- 4) A Delphi process, properly managed, can be a *highly motivating task* for respondent experts. If Delphi designers are imaginative in their analysis, feedback and construction of the sequential questionnaires, the Delphi method can provide a novel and interesting way of exchanging and distilling information from the experts involved (p. 21-22; *emphases* in original).

Later on in this chapter, many of Sackman's overarching concerns about Delphi validity, the reasonably successful rebuttals of Goldschmidt and Linstone, and the admonitions of Ziglio will be considered with a view to exercising due caution in the application of the Delphi method in this study. Many of the criticisms faced by Delphi studies rest with its methodological misapplication and not fundamental concerns about the technique itself. These considerations

will be addressed as the methodology developed for this proposed study is outlined in detail later on.

Returning now to Rieger's analysis of the quality of dissertations using the Delphi, he notes that the Delphi method passed through a series of distinct stages from its inception in the late 1950s to the early 1960s and then on to the 1980s. The stages identified were: secrecy and obscurity, novelty, popularity, scrutiny, application, and continuity. In addition, he cites a analysis of doctoral dissertations in education completed in Australia (n = 132) by O'Brien (1979) that were completed in the period 1970 – 1977 that raises an important point – virtually all of these investigations were applications of the Delphi technique “with a negligible number of dissertations dealing with an investigation of the technique itself.” (Rieger, 1986; p. 197)

Appealing once more to doctoral candidates' learning from Sackman's 1974 analysis and its cautionary tale, Rieger points out that users of the technique need to “heed basics” such as:

- Population sampling;
- Piloting procedures for the questionnaire;
- Questionnaire validity and reliability;
- Avoidance of uncritical acceptance of the rationale for the Delphi technique;
- Appealing to O'Brien's 1979 unpublished examination of theses and what was uncovered there;
- A recognition that only a minority of Delphi studies in dissertations were “well conducted” (his words);
- Avoiding a first-round questionnaire that is leading or not open-ended;
- Inadequate response rates (rate has to be >95% to be effective);
- Failure to establish questionnaire reliability (using the χ -square test for individual stability in the pilot phase test period to establish reliability); and
- Failure to survey those who left the study (drop-outs) to determine the causal and contributing factors.

Rieger's synopsis approves of certain dissertations that he felt were creative, innovative, and included careful research methodologies such as testing for role bias and participant fatigue among the Delphi panellists and for consideration for the "critical incident technique" in the general, first round questionnaire items. Finally, Rieger mentions that "it is refreshing to come across studies that openly state that the Delphi technique did not turn out to be the answer to the researcher's [methodological] problem. In an atmosphere where Delphi is often portrayed as an oracle with all the answers, such openness can only be helpful." (p. 201). Consonant with this view is a recent and intriguing treatment of the Delphi process as "ritual" (Marchais-Roubelat & Roubelat, 2011) wherein we are reminded that the technique could well be misnamed and therefore just as easily misrepresented. These authors point out that neither the original 1963 paper by Norman Dalkey and Olaf Helmer-Hirschberg nor the latter's 1983 book on forecasting and futures (Helmer, 1983) actually explain the origin of the term "Delphi". Moreover, we should be provided with a reminder that the ancient Hellenic oracles were notoriously obtuse and ambiguous in their answers, often providing just the opposite of clear prognostications. One example is that of the oracle (prophesy) delivered to Croesus: "If Croesus goes to war, he will destroy a great empire". Confident in the oracle's vision, Croesus indeed goes to war and his own empire perishes as the outcome. Linstone and Turoff (2002; p. 16) advise that "primitive man (sic) always approached the future ritualistically, with ceremonies involving utensils, liturgies, managers, and participants; the committee-free environment and anonymity of Delphi stimulate reflection and imagination, facilitating a personal futures orientation.". So too, a modern Delphi study could well include aspects that could be considered as "ritualistic".

The Delphi Method Modified – Adaptation to Graduate Studies in Science Education

The literature on the Delphi method and the use of its techniques was vast even more than a decade ago (Gupta & Clarke, 1996), and this reflects its influence as a qualitative/quantitative mixed-methods approach in the social sciences, the explosive growth brought about by the efficiencies of the Internet as a communications tool, and its adaptability to a rich variety of research environments – particularly those of management, education, and program development. The inverse of the literature base is the scant treatment given to the theoretical underpinnings of the Delphi technique, including identifying key moments in its historical progression and locating some of the problem areas with the approach within dissertations and theses. Virtually all accounts provide but a paragraph of devotion to these aspects of Delphi use and just as quickly launch into a justification for the technique for the study at hand (e.g., Cole, 2012). For these reasons I have elected to develop this background somewhat more fully in this chapter and include some recent commentary on Delphi techniques and their appropriate (or inappropriate) application.

A recent *ProQuest*[®] dissertation database search (globally) for the period 1970 – 2013 (using keywords methodology + Delphi+ study) yielded in excess of 13,000 studies using some form of the Delphi method in doctoral studies research in a wide array of disciplines – with healthcare, higher education and management fields having the greatest number of completed studies. Delphi studies in education are among the top five areas of application of the approach among doctoral candidates. The following table demonstrates the exponential growth in Delphi studies among dissertations and theses in education generally and in science education specifically over the period 1970 – 2019 (projected):

Table 1: Dissertations and Theses using the Delphi Method in Education, 1970 – 2019* (projected).

Decade	Education (all categories)	Science Education (EDU)	Proportion (Science EDU)
1970 – 1979	36	9	0.25
1980 – 1989	156	9	0.06
1990 – 1999	186	10	0.05
2000 – 2009	1,373	86	0.06
2010 – 2019 (projected)	2,700	180	0.06
2010 – 2013 (actual)	934	69	0.07

* Source: ProQuest[®] Dissertations and Theses; projections to 2019 are extrapolations.

When the search was refined to confine itself to education-related studies, the numbers were still very impressive at over 2,600 studies. Further refinement into specific fields of education provided some of the following (using Boolean paired keywords): teaching + Delphi = 409; curriculum + Delphi = 406; teacher education + Delphi = 338; secondary education + Delphi = 252; curriculum development + Delphi = 207; elementary education + Delphi = 118, and; science education + Delphi = 176). Of the theses and dissertations in science education having the Delphi method as included in the study, eleven of these were from Canadian post-secondary institutions with none earlier than 2005. The time span for Delphi studies conducted by doctoral candidates from American and international universities, by contrast, spans about 30 years. Table 2 outlines the details of these Canadian dissertations that made use of a Delphi methodology with their associated institutional affiliations. These are included here to provide a snapshot of the current state of Delphi employed in science education theses in the Canadian

context. The Delphi study in Canadian science education outlined in this dissertation adds to the diversity of these contributions, and distinguishes itself as the first such study in Canada to use the Delphi technique with a national-level panel of the expert community on matters related to science curriculum policy.

Table 2: Dissertations and Theses in Science Education from Canadian Universities using the Delphi Method, 2000 – 2013*.

Year	Thesis Title and Institution	Author
2012	Understanding of the nature of science: A comparative study of Canadian and Korean students. University of Toronto	Park, H.
2012	Towards a philosophically and a pedagogically reasonable nature of science curriculum. University of Alberta.	Yacoubian, H. A.
2011	Teacher beliefs about science education: Crucial to inform professional development initiatives. University of New Brunswick.	Marmen, D. R.
2010	The effect of classroom instruction, attitudes towards science and motivation on students' views of uncertainty in science. University of Calgary.	Schroeder, M.
2009	An interpretive inquiry into decision-making regarding the implementation of ICT amongst pre-service science teachers. University of Alberta.	Hur, S. J.
2008	Writing in science: Exploring teachers' and students' views of the nature of science in language enriched environments. University of Toronto.	DeCoito, I.
2008	An illustrative phenomenographic case study: Charting the landscape of "public understanding of science". University of Lethbridge.	D'Amour, L. M.
2007	Representing the nature of science in a science textbook: Exploring author-editor-publisher interactions. University of Toronto.	DiGiuseppe, M.
2006	An inquiry into the use of stories about scientists from diverse socio-cultural backgrounds in broadening grade one students' images of science and scientists. University of Toronto.	Sharkawy, A.
2006	Creative movement: A powerful strategy to teach science. University of Toronto.	Comia, A. C. R.
2005	Exploring teachers' beliefs and knowledge about scientific inquiry and the nature of science: A collaborative action research project. University of Toronto.	Fazio, X. E.

Source: ProQuest[®] Dissertations and Theses (science education and Canadian institutions as keywords in database search)

A Variant of the Delphi Method: Towards Policy Delphi and Issues of Curriculum

Since its inception in the 1950s, and certainly in the period of the 1970s as large-scale and diverse use of the Delphi method and its associated techniques became common, Delphi was usually applied to technical topics seeking consensus among a representative group of experts that was homogeneous. The policy Delphi, alternatively, “seeks to generate the strongest possible opposing views on the potential resolutions of a major policy issue” (Turoff 2002; [1975]; p. 80). Turoff was of the mind that where policy issues are at the centre of the inquiry, there are no experts but only informed advocates and referees. One can expect that issues of educational policy such as the current state and future of science education in Canada would be well-suited to differences of opinion, advocacy positions, and competition among the voices debating the issues at hand. Accordingly, the policy Delphi “rests on the premise that the decision-maker [researcher] is not interested in having a group generate a binding decision; but rather have an informed group present all the options and supporting evidence for consideration” (*op. cit.*; p. 80). Van Zolingen & Klaassen (2003) indicated that the aim of the policy Delphi was to generate policy alternatives through the use of structured, public (albeit anonymous) dialogue. With the prospect of obtaining many divergent views on an issue, Rauch (1979) claimed that the expert panellists were more than just experts, but lobbyists who will present and defend their own particular views. This, fortunately, invites polarity of group responses, structured conflict, and a tense consensus (if any). Turoff (2002; [1975]) was very clear about the prospects for this variant of the Delphi as being provocative. Consensus is not the primary objective here, and both the structure of the communications and the choice of the expert panel group would intentionally make consensus elusive to very unlikely. In fact, the researcher may design the Delphi in such a manner as to inhibit consensus formation among the group.

Policy Delphi is not a replacement of, or substitute for, techniques such as deliberative inquiry, focus groups, Nominal Group Technique, or the committee process. It is more likely used in a situation where it is advantageous to maintain anonymity and asynchronicity among participants while borrowing some of the desirable characteristics of these related inquiry methods. Schneider (1972) provided the following objectives of the policy Delphi, any combination of which can serve to inform a subsequent committee process:

- To ensure that all possible options have been put on the table for consideration;
- To estimate the impact and consequences of any particular option; and
- To examine and estimate the acceptability of any particular option.

Since the curriculum development process is a classic with regard to forming committee structures, a policy Delphi variant in this study is well-placed to possibly be that “informant” in subsequent discussions in Canadian jurisdictions with respect to science curriculum re-organization.

The policy Delphi has been utilized extensively in the examination of healthcare system issues, especially in fields such as nursing education (Benton *et al.* 2013; Keeney, Hasson & McKenna, 2006; 2011a;b; Keeney, McKenna & Hasson, 2010; McKenna, 1994), the development of policy options for infectious disease control such as SARS-like illnesses (Syed *et al.* 2010). Recent policy studies in education include multiple perspectives research on policy, practices, and delivery of K-12 distance education (Rice, 2009) and, in science education, policy Delphi studies of the future aims of science education in Romania (Gorghiu *et al.* 2013) the former Soviet Union republic of Georgia (Bolte *et al.*, 2012; Schulte & Bolte, 2012), Turkey (Trna & Krejčí, 2012), and in the European Union more generally (Paiva, Morais & Barros, 2012; Rundgren & Rundgren, 2012; Trnova, Trna & Vacek, 2013) have made use of policy-

oriented Delphi approaches. I had realized that there had yet to be conducted some form of a policy Delphi study engaging the expert community of science education in Canada.

Turoff (2002; [1975]) described the policy Delphi as a “very demanding exercise, both for the design team and for the respondents” and outlined the following six steps in the process (p. 84):

- (1) Formulation of the issues. What is the issue that really should be under consideration? How should it be stated?
- (2) Exposing the options. Given the issues, what are the policy options available?
- (3) Determining the initial position on the issues. Which are the ones everyone [on the expert panel] already agrees upon and which are the unimportant ones to be discarded? Which ones are exhibiting disagreement among the respondents?
- (4) Exploring and obtaining reasons for disagreements. What underlying assumptions, views, or facts are being used by the individuals to support their respective positions?
- (5) Evaluating the underlying reasons. How does the group view the separate arguments used to defend various positions and how do they compare to one another?
- (6) Re-evaluating the options. Re-evaluation is based upon the views of the underlying “evidence” and the assessment of its relevance to each position taken.

In order for a Delphi study to examine science education and curriculum policy positions in Canada, it was advisable to include participants who constitute the many sides of the issues under examination, be the most comprehensive assembly in terms of areas of interest, and therefore hope to achieve expositions of the strongest opinions and develop an architecture in the study that invites open dissent and contrary views. A challenge for the researcher, then, was to have more than just the appearance of competency in the area under examination – the researcher should be an aspirant to the expert community or one who already possesses the necessary

credibility. The study also sought the more subtle aspects of the problem areas at hand, and take as given the more obvious questions and secondary issues. Turoff (2002; [1975]) noted that (at least as of the mid-1970s) there had not been sufficient exploration into the use of the Delphi technique as a *process of education* among the participants. This is an important and natural consideration for the proposed study, that there be some prospect for the expert panel to become a learning community while the study is underway. A similar point was also identified by Schneider (1972) who pointed out that the representatives involved in the study could also self-organize under educational functions that would benefit both the researcher and those assembled to render opinion and commentary.

Yet another unexplored use of policy Delphi approaches is some level of investigation into past policy actions. By way of example, there have been analyses (somewhat historiographical) of the manner in which the *Pan-Canadian Protocol on School Curriculum* (CMEC, 1997) has had an effect on science education in Canadian jurisdictions (e.g., Milford *et al.*, 2010; Yore & Van der Flier-Keller, 2011a; b), but no significant study in the direction of re-assembling the architects of this curriculum project and, more importantly, those tasked with translation into curriculum and implementation to participate in a *post-hoc* analysis of what was accomplished and implications for future curriculum policy formulation. To do this effectively, and to ensure that most or all of the policy options are on the table the policy Delphi must explore dissension, dissensus, and not encourage an artificial consensus by virtue of discouraging strong minority opinions or causing these to be unexplored such that the dissenting groups feel forced to leave the study. A policy Delphi is a forum for ideas and new idea-making. Its anonymity also provides some protection from critical, disconcerting information from leaking out of the panel of experts, a problem that is perennial for committee structures. The process also

places demands upon the researcher to be disengaged from a biased exercise, and be cautious in the manner in which participants' comments are edited, interpreted, organized, and perhaps neglected.

Appropriateness of the Policy Delphi Research Method to the Proposed Study

As stated earlier, the policy Delphi research method is considered useful in instances where the researcher seeks the exposure of expert opinion that can be generated in the form of dissensus, tension and conflict in addition to areas of broader agreement. 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. The structured flow of information to the expert panel involving a series of surveys and reciprocal feedback to the group allows such a group to deal with a complex problem without the expectation of a binding set of resolutions as a final outcome, and the anonymity of the process 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 method approach is appropriate on occasions where:

- The problem does not lend itself to precise analytical techniques but can benefit from subjective judgements 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. (p. 4)

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, and these help argue favourably for the technique in social sciences research and this study. Surowiecki describes the circumstances as follows:

“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 policy Delphi – diversity of opinion, independence, the creation of summaries of options, and anonymity.

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. Certain selected members participating in the study were no longer professionally active in their respective fields *per se*, but nonetheless were included among the participants to provide important historical perspectives - especially in areas that focus on the key moments in the last 40 years of Canadian science education and the degrees of impact or effect that such periods had on the system of science education.

A two-fold methodological question may arise here, and I will address it in two parts:

- 1) “To what extent does a study design such as the one developed here produce a uniquely *Canadian* study in the absence of a comparison?” and,
- 2) “How does one differentiate participants’ contributions as representative of knowledge about science education or simply random opinion-making about science education?”

In order to respond to the first question and the concern it raises about Canadian content, one can appeal directly to the face validity aspects of the participants in the study which are developed in detail later on in Chapter 4. For now, as a presage of the arguments presented there, I can offer as further evidence a comparison of the research presented here and that recently conducted by the Council of Canadian Academies (CCA) in terms of a ‘Canadian study’. The efforts of the CCA are supported by individuals who are members of these three founding Member Academies: The Royal Society of Canada, The Canadian Academy of Engineering, and the Canadian Academy of Health Sciences. Naturally, a precondition for membership in Canadian learned academies is being a naturalised Canadian citizen. In late September, 2014, the CCA released *Science Culture: Where Canada Stands – Expert Panel on the State of Canada’s Science Culture* (CCA, 2014). This national scan of science culture in Canada convened a 14-member expert panel which was multi-disciplinary in composition and was involved in a literature review,

commissioning a survey of science culture, and providing an inventory and analysis of programs supporting a culture of science in Canada. If the words “Canada” or “Canadian” were in any way a proxy for, or an indicator of, the Canadian nature of this inquiry these occur over 1,600 times in a report of 222 pages. That panel’s findings were viewed by the CCA as a “collective judgement based on the best available evidence” (p. xiv). Seven of the twenty-four expert panel members and reviewers working on this science and culture study conducted by the CCA were also participants or informants through the literature in the research presented in this dissertation.

In the *Science Culture* study, it was identified that “given the lack of internationally comparable data, there is no scientifically rigorous way of evaluating the strengths and weaknesses of Canada’s systems” (p. xx). Nevertheless, informed observations from a diversity of fronts were considered as constituting the best ‘available evidence’ and not an obstacle to proceeding with its analysis. A good measure of that available evidence in support of the CCA study took the form of published international studies over the last decade which could then be brought into focus with respect to similar attributes of the Canadian science culture. In a similar manner, the Delphi study here devoted itself to tapping the resources of an expert community – all of whom were Canadians (and many distinguished Canadians) – with substantial diversity of background in the sciences and/or science education, and did so with the inclusion of individuals whose span of professional experience exceeded 35 years.

One other important attribute, in my estimation, for a study to be ‘Canadian’ is context. Though it is recognised that this study sought to determine many of the global issues and trends which could affect and be drivers of change in Canadian science education, these effects will occur within the context of Canadian society, no one else’s. The CCA study, in its final reflections on a science culture going forward, we read:

Finally, the high levels of engagement with science in Canada do not necessarily translate into government mechanisms or institutions that prioritize incorporation of scientific evidence into public policy-making and dissemination of scientific research to the public. Such tensions speak to both the strengths of Canada's science culture and its potential weaknesses. While much of the evidence in this report suggests Canada benefits from a relatively strong science culture, Canada could learn from initiatives undertaken in countries in which governments and political leaders have been more active in promoting national or regional visions for science culture and in providing ways for the public to meaningfully engage in discussion about scientific research and issues. Canada could also benefit from a more systematic approach to periodically assessing its science culture and to critically evaluating initiatives, programs, and activities associated with formal and informal science learning and engagement. Finally, Canadians could also work with their peers around the world to develop a more robust evidence base for assessing the adequacy of the institutional system of support for science culture, and to better track and understand the global drivers of science culture. (CCA, 2014; p. 186)

Therefore, Canada's unique geographic, societal, cultural, political, and educational characteristics will shape who any internal and external influences become operationalised. In particular, the historically situated aspects of Canadian life in relation to its Aboriginal citizens would represent one of the most highly visible and contested contextual factors which will be uniquely Canadian, and like nowhere else. To make this perhaps clearer, Canada is constitutionally bi-cultural and bilingual with the identification of two founding peoples. The functional reality of Canadian life is that its cultural diversity demands a broadening of the meaning of the term 'founding peoples', and this is still forthcoming. As far as the present study goes, Canadian context was certainly to emerge given the nature of the research questions. Again, Canada is like nowhere else. That said, however, the execution of a comparison study in the United States, Great Britain, Germany, or Australia holds a potential richness in illuminating

the degree to which American and other international influences have held a firm hand in the past of science education in Canada – a position stated at the very outset of the dissertation.

Knowledge, Opinion, and Knowledgeable Opinion in a Delphi Study

The second of the two questions holds importance enough to devote some special treatment of the query in a section all its own. 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 an 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 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 be condemned as hearsay, mere opinion, imagination, and grotesquely fallible. Therefore, there is confidence that all 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 knowledgeable opinion.

A second illustration of the differences among knowledge deemed to come only through sense perception (cf. Plato's arguments in the *Meno*), knowledge as informed judgement, and 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) comes to us in another Platonic dialogue – the *Theætetus* (Chappell, 2013). In the Θεαίτητος 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 dismisses his young student with a whim that all definitions of knowledge are, in the end, unsatisfactory. As we will see in Chapter 4, equating expert panel responses to opinion-making together with having some level of knowledgeable opinion on the matter is reinforced by the “accounts” which the participants in the Delphi Rounds II and III are required to provide in addition to their ratings on scale items.

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 and outlined later in Chapter 4.

In order to determine 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 research community impact factors (i.e., the most widely cited, with > 400 direct citations as of August, 2013, with 198 Delphi studies among these citations).

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 obvious advantages outlined earlier in this chapter. Among the perceived difficulties identified by Osborne *et al.*, the following are pertinent: (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 problems with 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 study conducted by Osborne *et al.* has important consistencies and parallels with the study developed here and with that of Abualrob & Daniel (2011;2013) – particularly with respect to decisions about choice of participants. In the Osborne study, twenty-five experts who were actively engaged in the study of science or its educational or communications aspects were among the choices to comprise the expert community. These included leading scientists; historians, sociologists and philosophers of science; science educators; and a supporting cast of

those engaged in the public understanding of science or involved in science communications or media. In their study, international stature, publications record, and acknowledged expertise were the primary criteria for selection alongside “acknowledged expertise in researching the processes and practices of science” (p. 698). In the case of teacher participants, Osborne *et al.* included five who “had achieved some public recognition for their work such as individuals who had won national awards for the quality of their teaching or were authors of science textbooks in widespread use” (p. 699). When consideration of how teaching award nominations and textbook writing contracts are awarded is accounted for, these authors were wise in disclaiming that “the notion of expert [science teaching] is not commonly agreed upon” (p. 699). The selection process for establishing the expert community is a problematic, often ill-defined, and somewhat subjective task indeed.

The Delphi Method: The Literature Informs the Sample Frame and Sample Plan

Why a Delphi? What follows is a series of positions and arguments which support the choice of a Delphi methodology for this study as opposed to alternatives which were viewed as obstacles to success. Since this study’s research design upon the subjective judgments of an assembled expert panel in the field of Canadian science education, there were certain properties that were encouraged to occur – among them engagement, enthusiasm, motivation, sustainability, team-building, and asynchronicity. These are among the most desirable characteristics for this study. According to Rotondi & Gustafson (1996), the promotion of team-building in the Delphi can diminish or remove some of the barriers among the participants towards a more in-depth conversation around the issues. For the purposes of this study, any

parameters that would create obstacles to engagement, enthusiasm, motivation, or sustainability were to be avoided through direct facilitation. For Rotondi and Gustafson, given that the Delphi process often requires many weeks to months of direct participation (this study required the expert panel to work for 17 weeks), an important factor is initial motivation to participate and then finding ways to sustain that motivation. In order to elicit and maintain a desirable level of motivation, Rotondi and Gustafson pointed out a number of characteristics that should be apparent:

- 1) *Tension for Change* - participants should feel a `tension` for change, meaning they should be dissatisfied with the current set of issues and concerns around which the Delphi exercise focuses. They should believe that change is essential, generally, as well as their vetting their own situation and points of view;
- 2) *Perceived Group Need* - participants should feel strongly that the group is one mechanism by which change can be initiated, and that they would have been unlikely to bring it about alone;
- 3) *Timing* - the participants need to believe that the Delphi process is not merely an academic exercise. The timing, the circumstances, and having the knowledge that others of the expert group also believe that a unique opportunity exists to inform a future course are sustaining qualities in any Delphi study and warrant their inclusion;
- 4) *Potential for Personal and Professional Growth* – for participants, a reason for devoting the time and energy to a Delphi process is also about holding a belief that participation in the exercise will bring about growth and change – in the person and in the group. This can take the form of a change in values, attitudes, or behaviour; or, a greater sense that their participation in the study will provide enhanced esteem and influence within the organization for which they operate. (p.40)

In this study, each of these was made manifest in some way, often through personal communications about the process to the researcher but most often in the commentary provided in responding to items within the questionnaires themselves.

One other property of the Delphi method which was naturally included within this study is that of asynchronicity. Ziglio (1996) and Turoff and Hiltz (1996) both pointed out that being able to participate asynchronously is one of the least understood qualities of an effective Delphi (since it is generally viewed as a consensus-oriented group process) along with being one of the most obvious qualities; and, since almost all computer-based or online Delphi studies make use of this characteristic it is one whose importance has real significance in modern usage. The asynchronicity has two primary focal points: expert panel members may choose to participate in the group communication processes when they feel they want to or are best able to, and; they may choose to contribute significantly to aspects of the problem for which they feel most qualified and less so in other areas of the information flow. (Ziglio, 1996; p. 10; Turoff and Hiltz, 1996; p. 58). In this study, in all instances where respondents did not feel that their background and expertise could be brought to bear on some component, they were offered an exit strategy – usually in the form of selecting an option that “I am not qualified to respond”.

In terms of sample frame and sample plan, the literature did not provide clear direction on the relationship between the scope of a given study and a specified formula for the number of participants on the expert panel (Keeney, Hasson & McKenna, 2006). Ludwig (1997) examined a number of Delphi studies and had this to say about the sample frame:

“ Selection of who to include in a Delphi forecasting study is critical. The majority of Delphi studies have used between 15-20 respondents and run over periods of several weeks. The number of respondents was generally determined by the number required to constitute a

representative pooling of judgments and the information summarizing capability of the research team. Large numbers of respondents generate many items and ideas making the summarizing process difficult.” (p. 2).

Debecq, Van de Ven & Gustafson (1975) suggested using the minimally sufficient number of respondents. Dalkey, Rourke, Lewis & Snyder (1972) reported there was a definite increase in the reliability of group responses with increasing group size. Reliability, with a correlation coefficient approaching 0.90, was found with a group size reaching approximately 13 participants. Ludwig (1997) also commented that

“Who is invited to participate in a Delphi futuring exercise should be carefully considered. Randomly selecting participants is not acceptable. Instead, characteristics and qualifications of desirable respondents should be identified and a nomination process used to select participants. Because the group number will be small (12-15), the researcher needs to locate and target individuals who are "expert", have knowledge and experience to base their futuring activities upon, and are self-motivated. Delphi should not be used with groups that have difficulty in reading or expressing themselves in written communication” (p. 2).

For this study, it was initially anticipated that approximately 75 “experts” in Canadian science education and allied fields would be provided an invitation to participate in the study. Of these, if 25 to 30 eventually agreed to become engaged for the duration of all Delphi rounds of the study, then prospects for a reliable set of outcomes appeared good. What took place far exceeded these expectations. The initial sample pool comprised N = 130 invitees, with N = 54 eventually agreeing to participate as of the beginning of Round 1. The Delphi method relies upon non-random samples to assemble the expert panel, and the literature consistently supports and approves of the researcher holding responsibility for the selection. However, given the time commitment for full participation, it is noted here that clear definition of the time commitment

should be provided at the outset with perhaps an honorarium to participants where no ethics obstacle prevents such an incentive. A database search among doctoral dissertations since 1981 demonstrated that, among theses and dissertations employing the Delphi method which provided explicit reference to sample size and numbers of rounds in their abstracts, there is great variety in numbers of rounds required and the number of panellists who comprise the expert community. Despite these variations, three Delphi rounds among an expert panel of between 15 and 30 members seemed optimal.

The next chapter addresses the purposes of the research, research questions, research design and methodology using a modified Delphi technique, instrumentation and questionnaire development procedures, and procedures for data collection and analysis.

Chapter 4: The Methodology

This chapter addresses the purposes of the research, research questions, research design and methodology using a modified Delphi technique, instrumentation and questionnaire development procedures, and procedures for data collection and analysis. Historically, the Delphi method has been used by researchers as an iterative process 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 makes use of expert opinion among individuals who share a diversity of interests in the enterprise of science education from across Canada. Taken together they comprise two distinct, asynchronous cohorts of specialists – these will be called “oracle cluster groups” – that constitute an expert panel for the purposes of establishing the important trends affecting, and the foundations and goals for, the future of science education in Canada in the post-2015 period.

One cohort of expert opinion (COHORT 1, N= 29) includes membership from among science academics, science curriculum specialists in provincial/territorial ministries of education, teacher-educators in faculties of education, practicing science teachers, medical educators, those working for science-based NGOs, science media and public outreach organizations, and the science and technology (R&D) community in Canada. All members of COHORT 1 share in a common chronology. That is, all were students in the K-12 formal education system at the time the Science Council of Canada released its recommendations (SCC, 1984c) for changes to the

approaches, goals and objectives for Canadian science education. COHORT 1 has the distinction of being a younger, more recent group of practitioners in science or science education since the era of the mid -1990s to the present. The rationale for isolating such a group in time is two-fold: 1) the members of this cohort of expert opinion were students in the system of Canadian science education at a time when research, policy development, curriculum development and implementation, and science teaching were quite fluid and in the midst of well-funded national efforts at reform, and; 2) this cohort is now active in many of the same aspects of science education just listed in (1), but in a time where the emphases in Canadian science education are likely to be quite different from earlier periods – those emphases being from among science literacy, system accountability through specific learning outcomes and standards for students, the influences and implications for curriculum policy emanating from the results of national and international assessments for students of science (examples of which include the Pan-Canadian Assessment Program (PCAP), and the Programme for International Student Assessment (PISA)), and globalizing effects provided by an integrated world economy.

The second cohort of expert opinion (COHORT 2, N = 26) also comprises science academics, science curriculum specialists in provincial/territorial ministries of education, teacher-educators in faculties of education, practicing science teachers, medical educators, those working for science-based NGOs, science media and public outreach organizations, and the science and technology (R&D) community in Canada. However, what distinguishes COHORT 2 is the following: this cohort group had activity in curriculum policy development from the post-Sputnik period of the early 1960s, through the emergence of the science-technology-society (STS) movements in the 1970s, and on to the high-profile “science for all Canadian students” and science

literacy movements of the 1980s. Therefore, at the time COHORT 1 was in formal schooling, individuals in COHORT 2 were in the midst of their professional careers – either connected to science education directly or interested in its processes and products by virtue of their career orientation. Presently, many of these individuals have earned distinctions in Canadian society (e.g., The Order of Canada, fellowship in a learned society, activity in the Council of Canadian Academies, and professors *emeriti*). It is, therefore, a veteran cohort and one of some experience.

Purpose of the Research

This proposed study seeks – through an anonymous and asynchronous Delphi process using two cohorts of science education specialists – to engage a select and criterion-referenced community of expertise among Canadian science educators to determine, and perhaps give novel definition to, the foundations of a Canadian approach to science education in Canada. The literature supports the presence of at least three significant episodes – I prefer the term “trajectories” – of science education reform movements that have altered the course of curriculum policy in Canadian jurisdictions. Though it is self-evident that in the Canadian federation of provinces and territories there are strong traditions and constitutional guarantees of independence where matters of curriculum and broader educational policy are concerned, there is (and has been) ample opportunity for inter-jurisdictional collaboration on matters of curriculum and mutual concern. The knowledge, opinions, recommendations and learning that were anticipated to come forward from the expert panels engaged in this study are certainly applicable to the levels at which curriculum, instruction, assessment, and science education policy are determined.

Development of the Research Questions

Over the period October, 2012 to January, 2013, I sought to frame the research questions and this required seeking after some informal discussions about the last 30 years of science education in Canada from certain leading Canadian science educator colleagues. In order to provide some degree of face validity to the development of the research questions, online citation indices databases were used to determine the most cited Canadian science education specialists of the period 1960 to 2012. From that list, efforts were made to make contact and engage in informal conversations with some of these individuals. This was done to generate some personal thinking about what characteristics are ideal in establishing criteria for expert panel membership and to discover individuals whose influences on science education and personal experiences in the Canadian context may hold some significance. Publication records, citation impacts, or anecdotal opinion did not provide the sole criteria for expert qualification. Peer influences and professional reputation were also considerations. Delphi studies have, on occasion, relied upon peer-selection influences as a primary consideration in the selection of an expert community (van Zolingen & Klaassen, 2002; Scapolo & Miles, 2006).

Of those contacted, three responded and demonstrated an interest in having informal discussions about the proposed study, its questions, and its orientation to the future of the Canadian experience. These early discussions were helpful in getting a sense of the prospects for determining the basis for a pathway forward some 17 years after the Pan-Canadian Protocol and 30 years after the Science Council of Canada study. As it would turn out, this group of correspondents resembled a Canadian, multi-generational academic science education group who held certain common connections to the last 40 years of science education research and curriculum policy. In addition, these individuals have had academic connections as mentors to their respective graduate students,

some of whom now form a sort of Canadian science educator “pedigree” providing a ‘generational’ aspect. In part, this was how the decision was arrived at to set up a double-cohort study.

It was deemed appropriate and important at this early phase to determine if there were prospects for knowledge generation in the first instance (the “theoretic” of Aristotle and Joseph J. Schwab) as opposed to determining a means to change curriculum policy and practices in science education in Canada which would be more inclined to the “practical” in the Aristotelian and Schwabian senses of the term. According to Orpwood, “the Science Council of Canada project was designed not only to change participants’ ‘understanding’ of how science education could and perhaps should evolve, but also to create the desire and will among participants to actually make the directions chosen in their deliberations into realities.” (personal communication, December 6, 2014). Using this distinction between the ‘theoretic’ and the ‘practical’ it was immediately recognized that the former (e.g., how science education in Canada could evolve) should be made a desired outcome of this study. It was further recognized that the ‘practical’ is more properly the prevail of the respective Canadian jurisdictions who are tasked with both the mandate and the direct authority to construct curriculum policy for their systems of education. An intriguing set of questions emerged if one were to accept such guiding assumptions, for instance: “What would comprise the principal theoretical foundations and processes of a *Canadian approach* to the development of science curriculum frameworks? “If the opinions from an ‘expert community’ which was uniquely Canadian in its orientation was given a forecasting voice in a future period of science curriculum reformulation to reflect Canadian aspirations, what might that look like?”. How might such questions, along with other associated questions be answered? What follows are the research questions that guided this study and this is followed by a detailed outline of the modified Delphi methodology which was used to collect the data for analysis.

The Research Questions:

Primary Research Question (PRQ):

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 the post-Pan Canadian Framework period?

Ancillary Research Questions (RQ):

1. What trends and conditions – both domestic and international – will serve to initiate and have defining influence upon future science curriculum change in Canada? (RQ1)
2. What characterises consensus (or 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? (RQ2)
3. What characterises 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? (RQ3)

Choice of Expert Panel Members

According to Yeh *et al.* (2013) and Hsu and Sandford (2007a) there exists no established framework or criteria, or specific recommendations for selection of members of the expert panel; however, since any outcome of a Delphi study is predicated upon – and reliant upon – expert

opinion, one expects that the results are only as stable, representative, and noteworthy as the acknowledged expertise of the expert panel itself. The literature is very clear on this point that constitutes the face validity of the Delphi (Hsu and Sandford, 2007a;b; Murry and Hammons, 1995; Yousouf, 2007 a;b). Hasson, Keeney and McKenna (2000) – who have worked primarily in Delphi studies related to nursing education – recommended the use of a sort of “gatekeeper” who could assist with panel selection with a view to increased access to participants by the researcher and bolster credibility, validity, and authenticity of the study. For this study, that initial ‘gatekeeper’ mechanism rested with the science education community itself given its traditions of peer recognition. That is, individuals who were held in high esteem by current colleagues, who held membership in learned societies, who were associated with scientific and/or educational academies, and those who had high impact indices in terms of publication citations for their work in science education were considered as self-identified by record of achievement. In support of expert community identification and eventual membership in a Delphi study panel, Mitchell (1991) provided three ways of guarding against a large portion of the subjective element in panel selection:

1. During the literature review, note the names of prominent figures in the field among the publications accessed;
2. The panellists selected had to have significant involvement in the field both in the past and in the present. [Direct] connections over the past five years was stipulated as a criterion, with many panellists having much more experience, and;
3. Panellists had to be recommended by fellow panellists. At the early, informal interview stage panel members were asked to name other experienced figures within the field. A panel member had to be mentioned by at least half of the interviewees before being [considered] for acceptance (Mitchell, 1991; p. 340).

Mitchell did admit that it is “usually left to the researcher to decide, on an arbitrary basis, how experts’ knowledge was to be evaluated” but as far as panel selection was concerned it was “methodologically essential that the criteria are divulged [and] that they are applied uniformly” (1991; p. 340). Mitchell goes on to offer that, in his estimation, “no reported Delphi study has directly addressed this selection [acceptance bias] issue”. There are complementary cautions raised by Surowiecki (2004) with respect to experts and their role playing. In an interview, when asked “Why are we not better off finding a single expert to make all the hard decisions?”, Surowiecki claimed that:

“Experts, no matter how smart, only have limited amounts of information. They also, like all of us, have biases. It's very rare that one person can know more than a large group of people, and almost never does that same person know more about a whole series of questions. The other problem in finding an expert is that it's actually hard to identify true experts. In fact, if a group is smart enough to find a real expert, it's more than smart enough not to need one.”

Since representative opinion-making for this study could not possibly derive from random sampling of a ‘universe of experts’ nor have access to a census group, the possibility of sampling error within a purposeful sample was considered. As we will see in the data analysis sections of Chapter 5, only descriptive statistics are utilized. Inferential statistical analyses are beyond the sampling scope of this study by virtue of the expert panel not being constitutive of a randomly-selected and representative group. Notwithstanding, such a practical limitation is within the limits of a well-constructed Delphi study and is understood to be present with any Delphi approaches. At the same time, reliance upon the judgement of the expert community itself (i.e., peer influences) to identify its own is construed as an asset – not a deficit – in the instance of a policy Delphi study.

And so, during the period October, 2012 to January, 2013, the researcher sought to sample frame the research community in Canada towards establishing a select group of Canadian science educators (and those with a particular interest in science education) who would be well-positioned to recommend co-participants in the study. In order to provide some face validity to this informal process, the researcher used online citation indices databases to determine the top five most cited Canadian science education specialists of the period 1960 to 2012. From that list, efforts were made to make contact and engage in informal conversations with these five individuals in order to generate some opinion-making about who – or from what occupations or research profiles - such a select list could be compiled from the perspective of influences on science education in Canada . This process was admittedly partially *ad hoc*, but was not confined just to publication records, citation indices and impact factors, awards granted, or casual opinion. As of this proposal writing, six (6) individuals with a combined experience of more than 200 years of science education research and teaching experience have indicated a willingness to participate as a third-party selection panel for participants who would receive invitations into the study.

Criteria for Inclusion on the Expert Panel

For this study, the expert panel of participants 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, 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 an award for career contributions to the teaching of science, 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 for having been a practitioner or researcher in the sciences, allied fields, or science education within the era of the early 1960s to the 1980s (and beyond); these were further identified by peer influences together with the researcher's opinion as being a respected expert in their field through a combination of publications, formal and informal presentations, noted contributions to schools, school divisions, curriculum and program development, learned societies, or participation in organisations dedicated to the advancement of science teaching and learning.
- 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 above criteria are aligned with selection criteria used by van Zolingen & Klaassen (2003) to compose a heterogeneous group of experts likely to have a diversity of opinions, and are reasonably consonant with those used by Osborne *et al.* (2003) to exert strict controls on professional background. That study a decade ago is the only national-level (U.K.) Delphi study with a high incidence of citation (>450 citations as of December, 2013, and 17 more in the first 4 months of 2014) and having rather strict (if not parochial) expert selection criteria. In the Osborne *et al.* study, a three-stage Delphi questionnaire sampled the opinion of 23 participants drawn from the communities of leading and acknowledged international experts of science educators; scientists; historians, philosophers and sociologists of science; experts engaged in work to improve the public understanding of science; and expert science teachers. The voices notably absent from the international 'expert community' in the Osborne study were the voices of the British government responsible for its national curriculum and its students. This was intentional given that the focus of deliberations in their study was the role of the nature of science in the school curriculum, an area without expectations of expertise among students of

science nor the desired influences of the bureaucracy. For this study, the role of students – be they K-12, undergraduate science majors or science education majors, and graduate students – remains an unsolved problem in terms of the ability to provide appropriate levels of expertise and so were excluded.

Selection Process to Establish the Expert Panel

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 ones 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

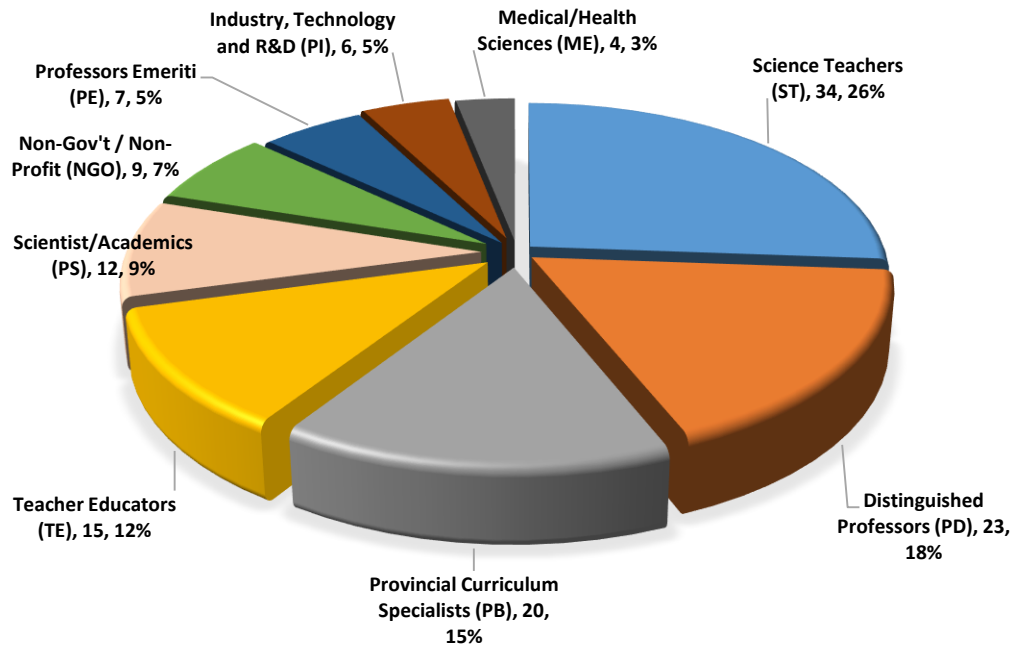
- A randomized selection from among Tier 1 and Tier 2 Canada Research Chairs in the natural sciences, science education, and engineering generally representative of dispersion in Canada (N = 830 in random sample where $N_{(\text{selected})} = 20$)

The final list of candidates for participation in the study (N=130)² was comprised of the following (see also Figure 4 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)

² 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.

Figure 1: Invited Candidates by Professional Affiliation.³



There was no emphasis 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.⁴ 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:

³ 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).

⁴ The gender imbalance in the purposeful sample was the result of position, occupation, or in accordance with satisfying the selection criteria.

Figure 2: Invited Candidates by Professional Distinction and Gender.

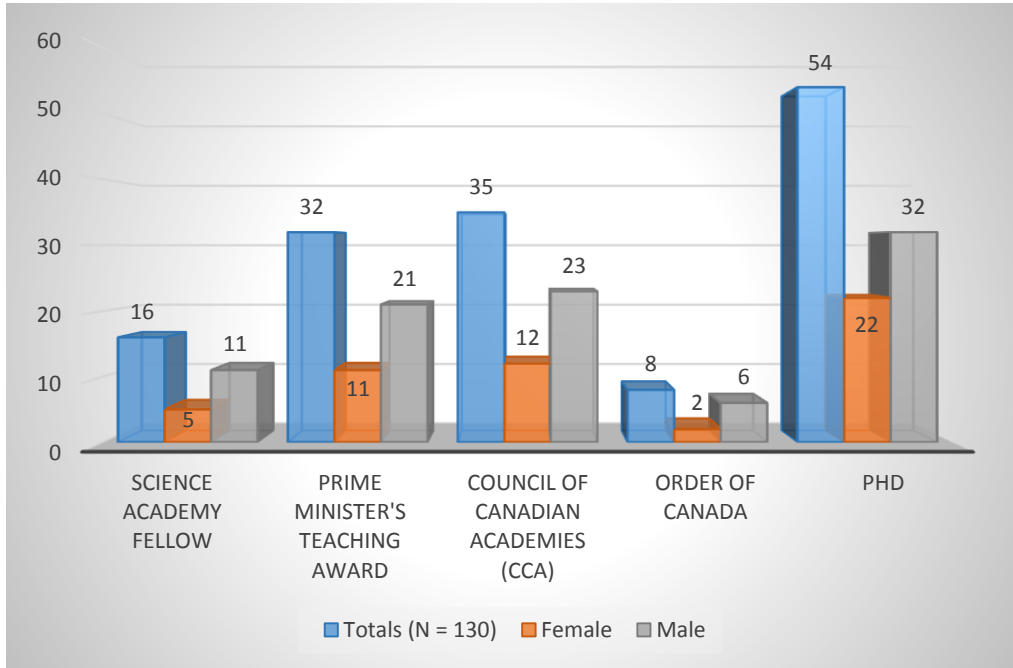
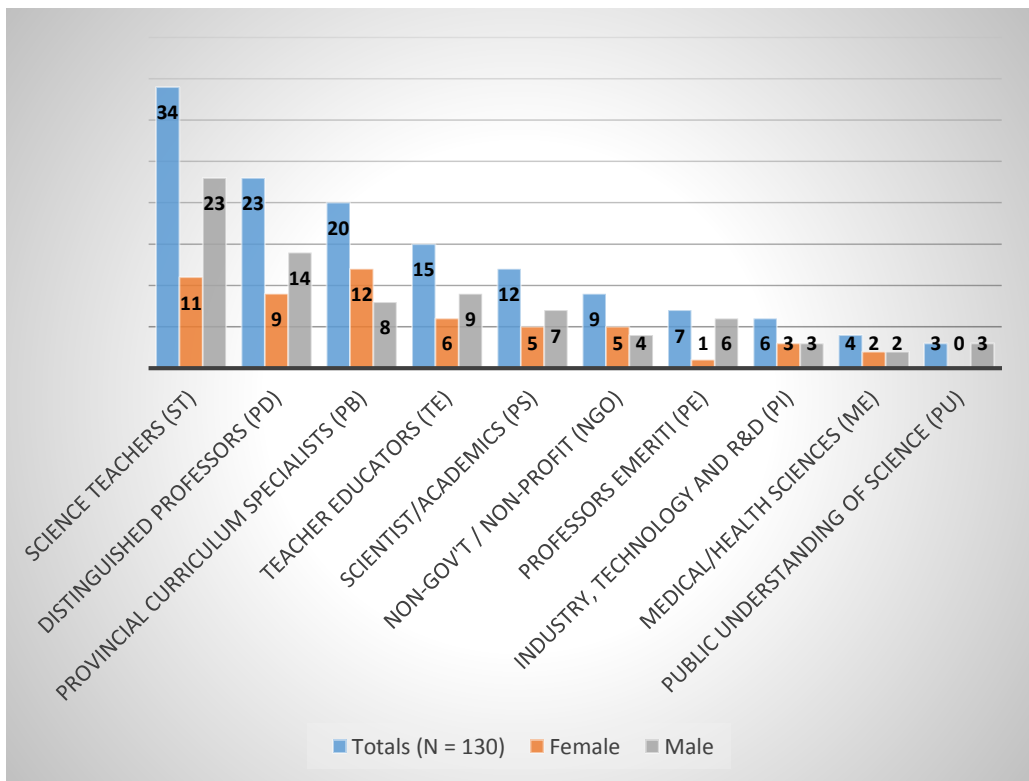
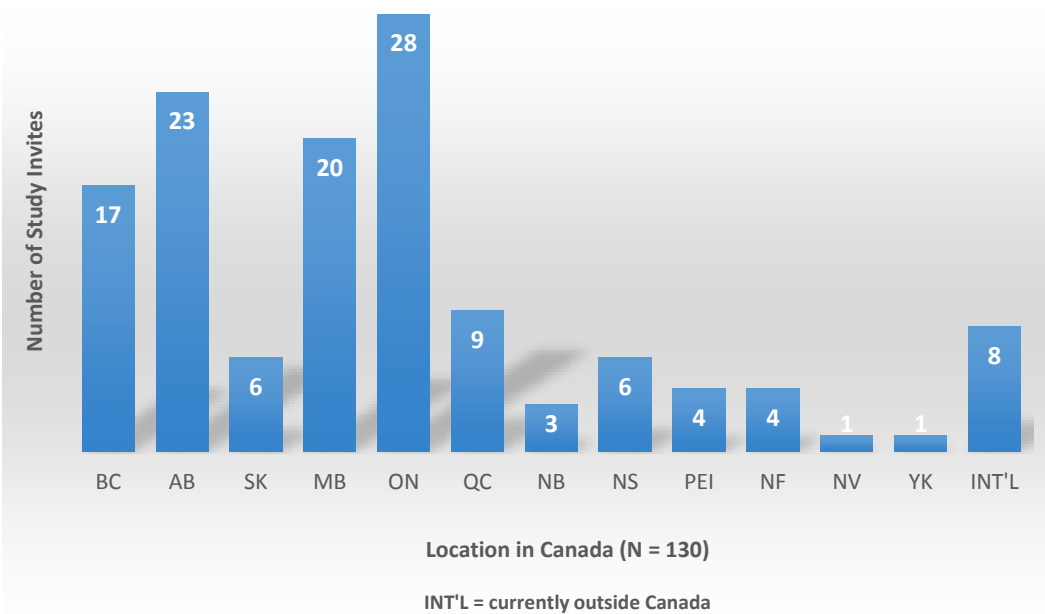


Figure 3: Invited Candidates by Profession and Gender.



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. Figure 4 below outlines the geographic distribution of the candidates:

Figure 4: Invited Candidates by Jurisdiction



In the period December 4 - 7, 2013, letters of invitation were sent via e-mail to all candidates for the expert panel (N = 130) with a follow-up version sent by surface mail in hard copy. These letters outlined the purpose, scope, and methodology of the study including a brief synopsis of the nature and processes involved in a multi-round Delphi study. Participant candidates were provided a 14-day period to consider the opportunity and respond to the Letter of Invitation. The letter of invitation also included information and contacts for the University of Manitoba Education and Nursing Research Ethics Board (ENREB) and stated the approved research protocol number (copies of the ENREB Protocol and the Letter of Invitation can be viewed in Appendices 'A' and 'B').

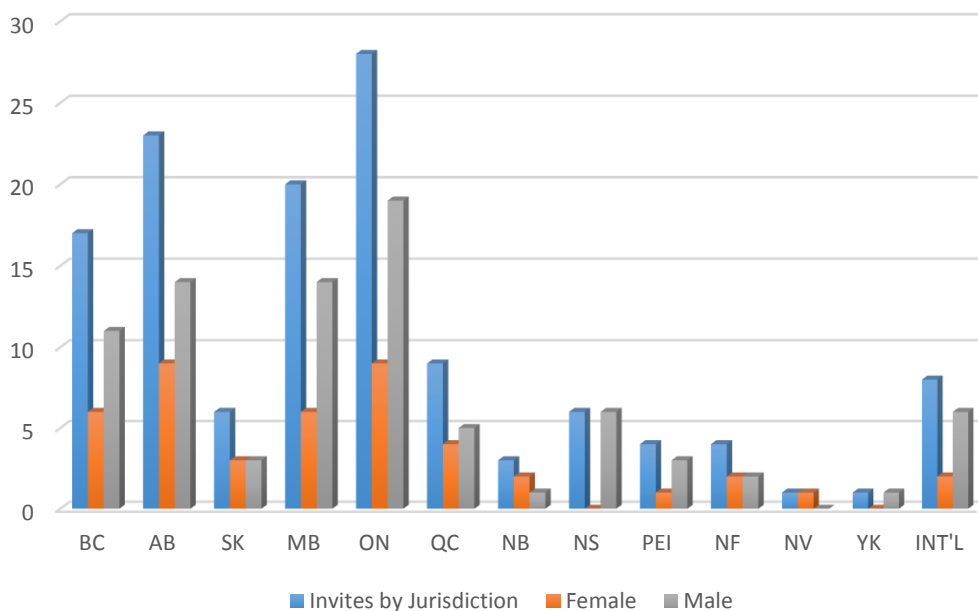
Of the participant candidates approached with an invitation, responses were received from 46 individuals who indicated “yes”, 45 indicated “no”, with 40 not providing a response either by email, telephone, or hard copy letter. A significant number of those declining to participate cited one or more of the following reasons:

- Insufficient time available to commit to the anticipated number of Delphi rounds;
- A sense that they were not positioned to provide “expertise to science education”;
- Bound by professional guidelines or internal organizational direction that would prevent participation in a study of this kind, even with guarantee of anonymity;
- Unable to secure a reliable online connection during certain active phases of the Delphi study

Figure 5 below provides a description of the invited candidates organized according to geographic region and gender. While it is clear that, nationally, the ratio of female:male in the sample is approximately 5:8, most Canadian jurisdictions demonstrated similar gender ratios from the sampling criteria (with notable exceptions such as SK, NB, NS, and NL). It is also instructive to note how the domains of professional activity which guided the sampling was

responsible for the production of a noteworthy gender inequality with only a single exception – the profile of science specialists working in provincial ministries of education (3:2 female to male ratio).

Figure 5: Invited Candidates by Jurisdiction and Gender.



Beginning December 18, 2013, an electronic Informed Consent Form was delivered to each individual who had agreed to participate (see Appendix ‘E’). Upon reaching the first week of January, 2014, confirmations for participation and agreement in principle had been received from all candidate participants. Most were comfortable with electronic delivery of Informed Consent while some preferred to sign in hard copy and return it via surface mail. The Informed Consent also included an agreement to participate in an interview (if called upon) as a part of the study. By this point, the number of confirmed individuals had grown from the initial N = 46 to N = 54. Of these 54 Round 1 expert panel members, 48 provided consent to be interviewed. What

had been a 5:8 female:male ratio among invited candidates had been significantly altered to N = 26 for female and N = 28 males through quite natural self-selective means. Though it has been mentioned that gender-specific analysis as an aggregate group is not a preferred outcome of this study – it is the viewpoints of participants that are at issue – there was a certain amount of relief to observe that there was to be improved balance across gender, at least in the bulk sample that would eventually fission naturally into two cohorts.

The modified Delphi method used in this study has an important reliance upon strict anonymity of participants. In the earliest period of Delphi at the RAND Corporation, it was repeatedly noted that “the traditional way of pooling individual opinions is by face-to-face discussion and deliberation. After face-to-face discussion, more often than not, the group response is less accurate than a simple median of individuals’ estimates *without discussion*” (Brown, Cochran & Dalkey, 1969; p. 14 *italics my own*)⁵. Linstone and Turoff (2002; [1975]; 2011) have reminded us that assurances of anonymity among the participants is of particular importance in a structured environment where the constraints imposed by public voicing of opinions imposes constraints on personal views. The Delphi method can significantly reduce the effects of dominant, articulate individuals who may actually have little of substance to contribute but do so in convincing fashion that causes the group to incline towards a false, reluctant compromise (Dalkey, 1967). In this study, prior to the start of Round 1, all participants were assigned a randomized 2-digit number between 01 and 99 as an identifier to enter the online questionnaire. Eventually, as the demographic data supplied in Round 1 was available, this ID Code was expanded to a 6-character alphanumeric (e.g., 1099ST, 2099ME) which identified

⁵ See also: Dalkey, N. C. and O. Helmer-Hirschberg (1963). An experimental application of the Delphi method to the use of experts. *Management Science*, 9, 10.

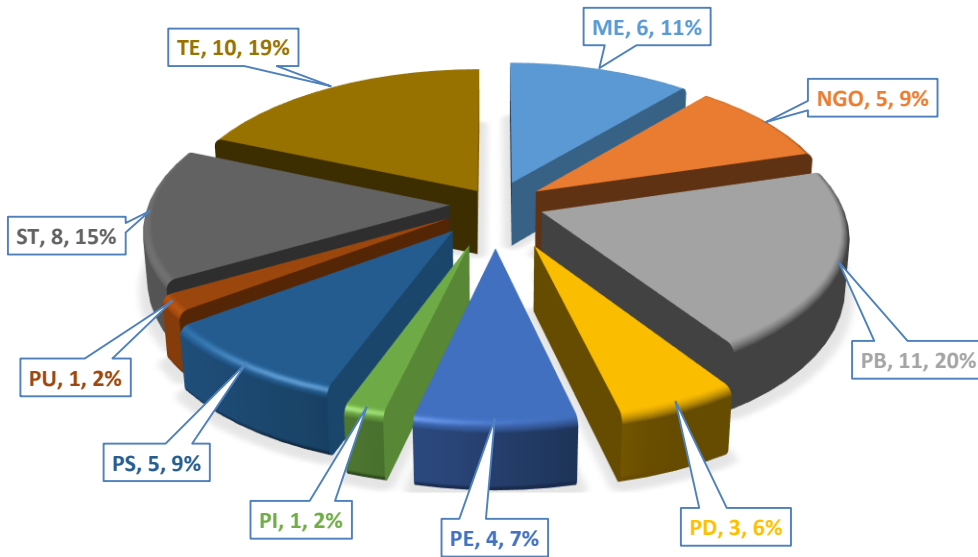
membership in the COHORT 1 or COHORT 2 group with added professional affiliations.⁶

Throughout the study, including the delivery of controlled feedback through summaries between rounds, this ID Code was the only provision providing some insight into participants' roles. No one had knowledge of which cohort they had been sorted into, simply the 2-character "tag" that highlighted professional affiliation.

It is instructive to compare the differentiation among those who were to become participants in Round 1 of the Delphi with that of the invited candidates (see Figure 1, page 136). Figure 6 below provides this differentiation according to professional affiliation, and the same legend applies:

⁶ In the examples provided here, 1099ST would be a K-12 science teacher in COHORT 1; 2099ME would be a medical/health sciences specialist educator in COHORT 2.

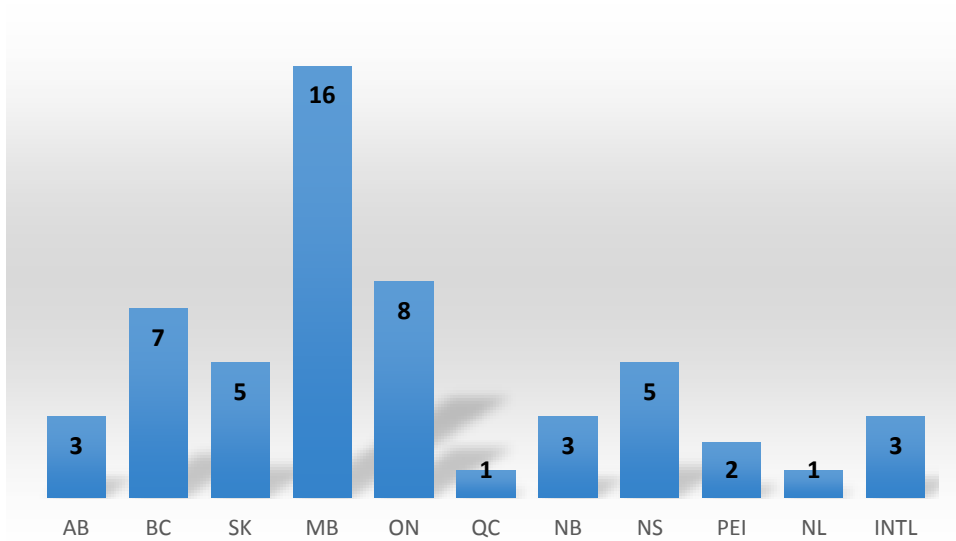
Figure 6: Round 1 Delphi Participants, by Professional Affiliation (cf. Figure 1).



Legend	
PI = Industry, Technology and R&D	ME = Medical / Health Sciences
ST = K-12 Science Teachers	PD = Distinguished Professors
PB = Provincial Ministry Curriculum	PS = Professional Science / Academic Science
NGO = Non-Government / Non- Profit	PE = Professors emeriti
PU = Public Understanding of Science	

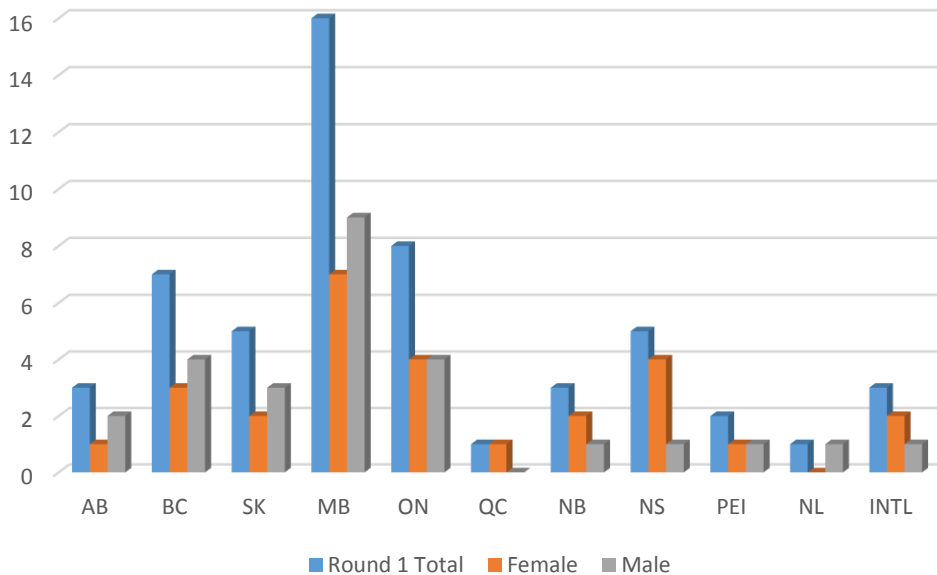
In terms of jurisdictional differentiation for Round 1, the initial candidate pool maintained a very strong presence from SK, MB, NB, and NS with lower participation rates among BC, AB, and ON. This is not surprising given that 12 of the 20 individuals from MB are well-known in the science and science education communities in the researcher’s province of residence and connected to the colleges and universities there. Mutual recognition likely played a role as well. Figure 7 below provides a profile of Round 1 participants according to geographic distribution:

Figure 7: Round 1 Delphi Participants, by Canadian Jurisdiction (cf. Figure 7).



The gender differentiation among those who became Round 1 participants, as mentioned, was a departure towards more balance in the assembled sample. Figure 8 below provides a profile of Round 1 participants (totals + gender):

Figure 8: Round 1 Delphi Participants, by Jurisdiction and Gender (cf. Figure 8).



Instrumentation and Procedures

Round 1 of the Delphi

It has been recommended by numerous, experienced Delphi study authors that the initial 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, encouragement was given to the expert panel cohorts to respond quite free-form (and at length) to four general questions that were intended to contextualize a basis for forecasting the nature of the Canadian science education experience for the next generation. It was important in this opening round of the Delphi to not unnecessarily direct the expert panel in any 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 panellist 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 panellists’ 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 panellists and the provision to them of “appropriate background information on the technique” (p. 10). To fulfil Ziglio’s recommendation, all participants were provided a brief primer on the Delphi approach both in the initial invitation to participate letter and in a follow-up email communication. On occasion, just prior to Round 1 opening, a few individuals asked for personalised 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.

In practice, the study made use of a well-known, online survey instrument application (i.e., FluidSurveys 4.1[®]) for the delivery of the questionnaires for each of three Delphi rounds. There is care that is required, and some experience needed with online survey construction. For instance, in a study of mixed methods surveying with six associates from the Gallup Organization, Dillman *et al.* (2009) determined that instrument font size, shading, the use of italics and other features can conspire to influence the kind and amount of information supplied by respondents. Parameters such as text box size for free-form expository responses, if appearing small, seem to invite proportionately shorter responses. The previous experiences that I had had in online questionnaire development – while in an earlier graduate degree program – proved very constructive. By way of example in this study, where certain expert panel members were expected to undoubtedly respond at length to certain of the first round free-form questions, it was important to explicitly state that the text boxes will expand in an ‘auto-fit to contents’ as the writer continues. Additionally, the study of Dillman *et al.* (2009) noticed differences in responses to the same questions delivered orally in a face-to-face interview mode as compared to online instrumentation. This informed and supported the need in this study to conduct semi-structured interviews (closely following the conclusion of the Delphi procedures) with members from the two cohorts of the expert panel who were deemed *representative* of the dominant themes emerging in the research in order to clarify the details of their written responses.

The following “seed questions”⁷ were offered for the consideration of the expert panel members in Round 1 which began January 10, 2014 (see Appendix ‘D’ for the complete Round 1 instrument):

⁷ This term has been adopted from that used by Russel King (2008)

- 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.

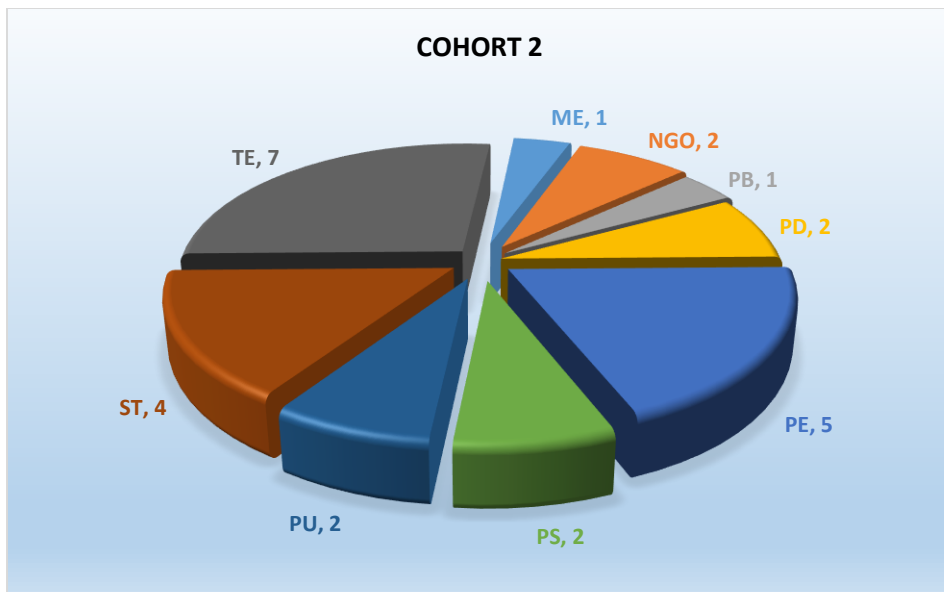
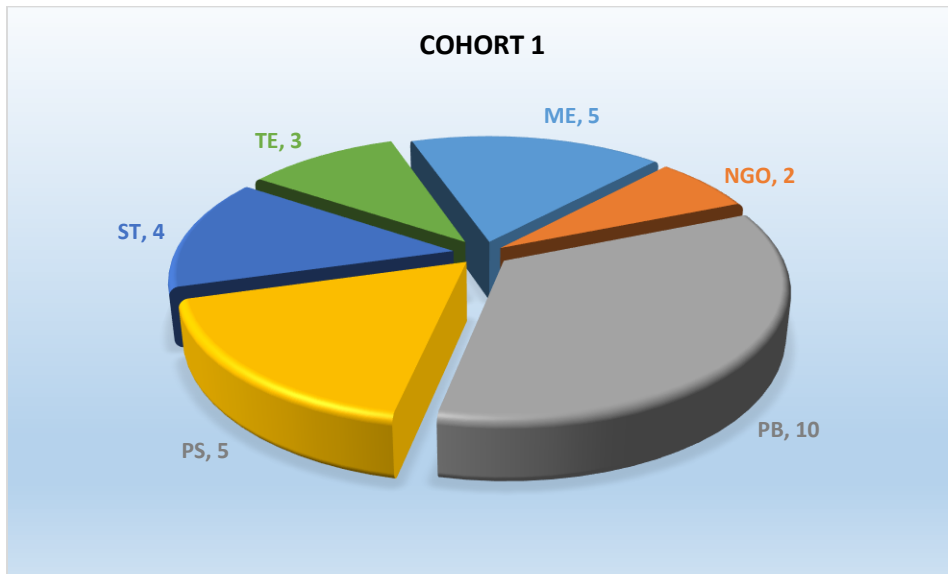
Selection Process to Establish the Expert Panel in Two Cohorts

This point in the methodology narrative provides a good place to outline the specifics of how the cohorts were arranged in Round 1. In addition to the large-scale “seed questions”, participants responded to a number of demographic data collection items. For the structuring of the research, the most important consideration from that section of the questionnaire was to be

able to separate the expert panel into two cohorts – COHORTS 1 and 2 - as described earlier in this chapter for the purposes of data analysis across all rounds of the Delphi. From the demographics section responses, it became possible to separate out COHORT 1 and COHORT 2, but with some adjustments to the criteria. The main adjustment was a chronological one. In order to have reasonably balanced cohorts geographically, professionally, and experientially, it was necessary to move the position of maximal perceived professional influence (PPI) further towards the present. Among the key indicators from the participant demographics which determined where that PPI maximum was, these included (but were not limited to): publication records and citation indices among academics, year of teaching award for K-12 science teachers, curriculum development projects (provincial or national) among staff of provincial ministries, or a significant career move in a field. In the end, it was necessary to move the threshold from COHORT 2 to COHORT 1 from its original position in the mid-1980s to the mid-1990s. The result of this change produced the following characteristics across the two cohorts (see Figures 9 and 10):⁸

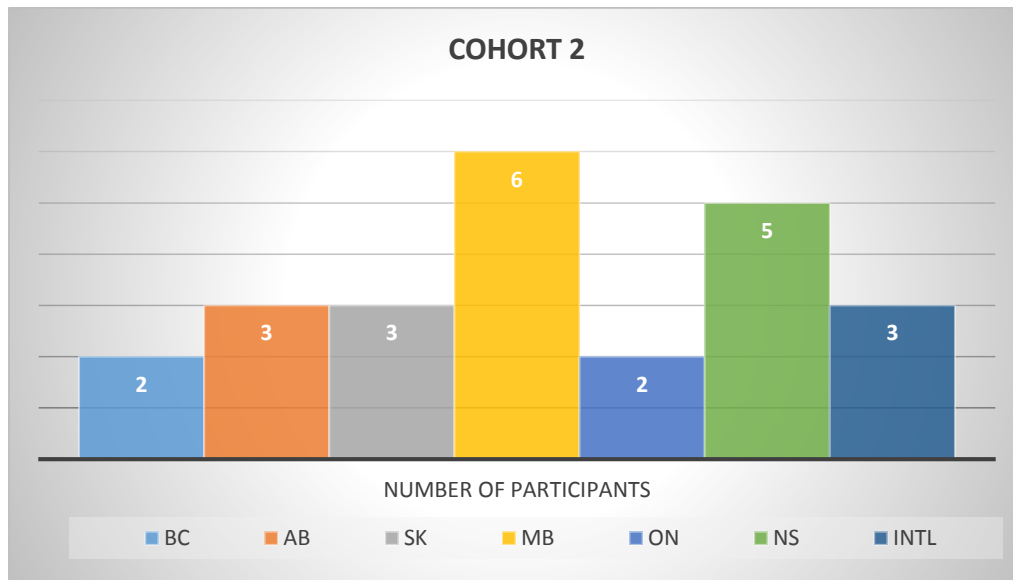
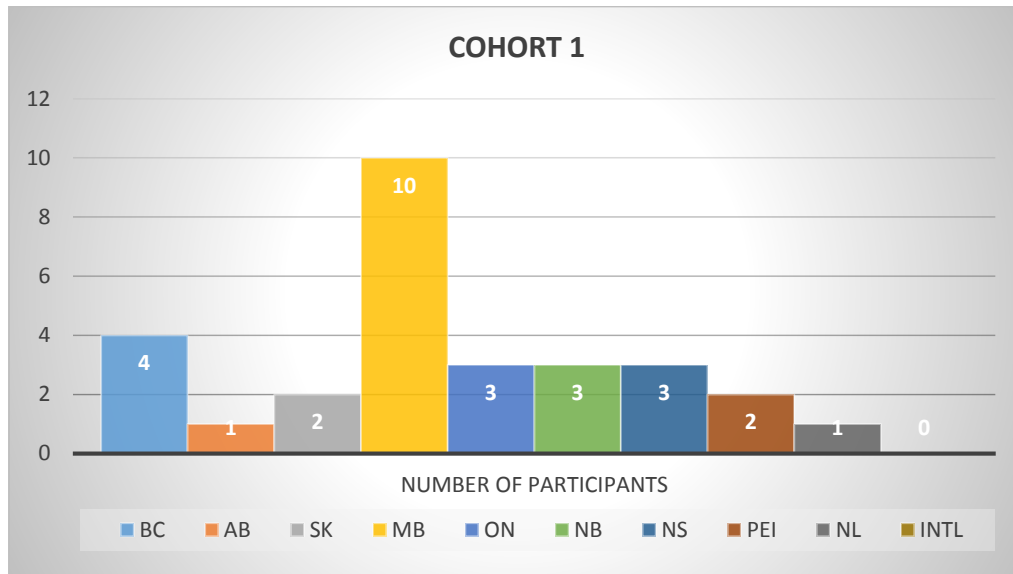
⁸ For details of the demographic items in response, these can be accessed in the Round 1 instrument in Appendix 'D'.

Figure 9: Round 1 Delphi Participants, by Professional Affiliation and Cohort (cf. Figure 3).



Legend	
PI = Industry, Technology and R&D	ME = Medical / Health Sciences
ST – K-12 Science Teachers	PD = Distinguished Professors
PB = Provincial Ministry Curriculum (Sci.)	PS = Professional Science / Academic Science
NGO = Non-Government / Non- Profit	PE = Professors emeriti
PU = Public Understanding of Science	

Figure 10: Round 1 Delphi Participants, by Jurisdiction and Cohort (cf. Figure 10).⁹



⁹ Note: Due to variations in the data, the bars in these figures are not similar in scale.

Coding Procedures for Participant Responses

NVivo 10™ computer assisted qualitative data analysis software (CAQDAS) from QSR International was used to code the written responses in order to determine the principal themes and critical incidents that emerged from the initial phase of the data collection in Round 1 (Flanagan, 1954; Hughes, 2007; Sinkovics & Alfoldi, 2012). All responses were coded reflexively and iteratively until a reliability of at least 75% was obtained. This coding was conducted in the following manner:

- 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 to 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 NVivo10™ using two or more similar concepts, explanatory ideas, or phrases (as outlined in (c) above).

These five coding procedures became the basis for identifying the *themes* in the data.

At the time the design of the study was being considered, it was anticipated that combined participant responses from COHORT 1 and COHORT 2 would cause to emerge a manageable number of major categories (approximately ten to twelve) that would constitute the primary themes which would then form the basis for development of rating scales in later iterations of the Delphi (i.e., Rounds 2 and 3). The number of themes that emerged, naturally by virtue of open coding, demonstrated that the initial estimate at the outset was far too conservative. Details on the number and nature of the themes is described later in a subsequent chapter and are provided in Appendix ‘G’.

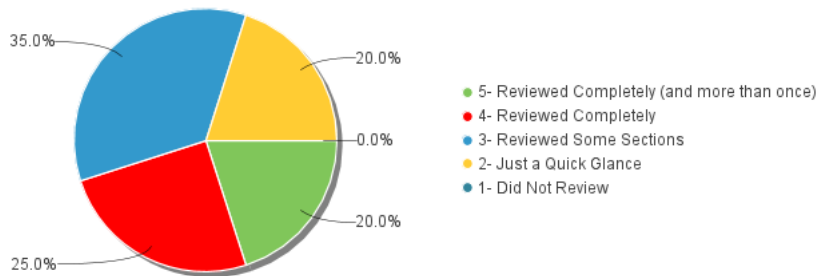
Round 2 of the Delphi

Once the Delphi process had reached the preparation stage for Round 2, it was an occasion to take the principal themes that had emerged from the Round 1 responses and prepare summaries of the themes to be delivered back to the participants. This is a crucial early stage for any Delphi study framework – controlled feedback into the expert panel during an interim period between rounds. By this point, each member of the expert panel had received a copy of their responses to the Round 1 questions. The theme summary document had the following attributes: (a) provisional theme titles, (b) a brief synopsis of the *justification for emergence* for the theme including

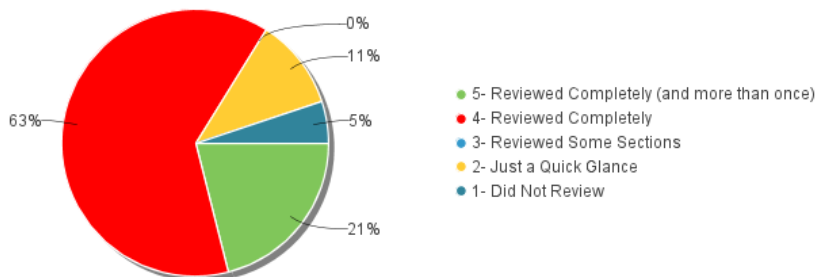
representative concepts tagged with alpha-numeric ID codes of participants, and (3) direct quotations (again with attached ID codes) from participants who provided compelling definition(s) to the theme. A sample summary report from Round 1 which was delivered to the expert panel groups can be viewed in Appendix ‘G’. Given the professional life schedules and commitments of the expert panel members, it was of interest to determine (via a self-assessment) the depth to which the Round 1 summary report was reviewed in between rounds. The figure (Figure 11) below demonstrates these levels of review as reported by the expert panel:

Figure 11: Expert Panel Member Self-Assessments of Review of Round 1 Summary Report.

COHORT 1



COHORT 2



The figure below (Figure 12) demonstrates its organization and appearance of the report:

Figure 12: Sample Page of Round 1 Theme Summary for Expert Panel.

Science Education in Canada – A Delphi Study

Science Education in Canada – A Delphi Study

ROUND 1 THEMES – GLOBAL TRENDS, FOUNDATIONS, GOALS AND CANADIAN CONTEXT FOR SCIENCE EDUCATION

QUESTION 1 | CURRENT GLOBAL TRENDS AND SCIENCE EDUCATION

Theme – Science, Technology, Engineering and Mathematics

Justification for Emergence¹

The Science, Technology, Engineering and Mathematics (STEM) theme includes references to its existence as a recent re-conceptualization of the core approach to the teaching and learning of science. For some, STEM marks a departure in the foundations of science education away from 'STSE as a planning approach to a distinct realignment from science for citizenship to science for skills development towards employment; especially innovation and leveraging the 21st century economy' (1022TE). It is a consideration that many 'future-oriented employment profiles will require a significant personal background in STEM' (1001PS) and that the direct teaching of engineering and design principles is 'important to international competitiveness in a globalized economy' (1067PB) and for the prospects of science and technology as 'drivers of the innovation' that leads to a prosperous economy (1098PU).

STEM is also viewed as foundational to the future architecture of science curriculum, teaching, and learning such that it provides a 'broadly acceptable national vision for science education' (1067PB | 1098PU) and a platform upon which 'diverse career opportunities across all post-secondary pathways' can be constructed by students. Interdisciplinary approaches that exist at the interface of STEM and the Arts (as STEAM) are viewed as a point of entry among 'disenchanted or reluctant generalist teachers of science' (2087PE | 2009ST). There is mention of the 'science-proficient worker' (2054TE) that will participate in an inevitably globalized future which will be characterized by increasing dependence upon the influence, the importance of, and the affordances provided by 'engineering, biotechnology, and other applied science fields' (2085PE).

Representative Statements²

- 1) According to Human Resources and Skills Development Canada, a great percentage of the jobs of the future require a background in STEM (science, technology, engineering and mathematics). | 1091PL
- 2) Globally there is also a need for STEM leaders. That is, leadership skills need to be taught alongside STEM subjects and integrated if possible. | 1001PS.
- 3) A reduction in teaching process skills such as inquiry and more emphasis on developing engineering skills such as problem articulation and solving. | 1066TE.
- 4) Concerns about sustainability, health, energy, and water are examples of significant issues that face today's societies and involve government policies and actions. These issues are interconnected with STEM. | 2001TE.
- 5) Growth of economic globalisation, growth of the economic impact of S&T, and the consequent growth of the importance of S&T education. 2065PE

Questionnaire development made use of Likert-type interval scales in most instances of item creation. Rating scales such as this have been recommended since the inception of the Delphi method and are repeatedly outlined in the seminal works available on the technique (eg., Linstone & Turoff (2002; [1975])). The rating scales developed in this study were usually dependent upon

a 5-point descending scale. The range of ordinal choices ranged, for instance, from a 5 = Definitely Relevant, to 4 = Very Relevant, to 3 = Relevant, to 2 = Slightly Relevant, and to 1 = Not Relevant. On occasion, where opinions on a potentially “polarizing issue” were sought, or one in which it was natural for an item to be viewed using end-member variables such as “important barrier” or “significant opportunity” it was deemed best to offer respondents a semantic differential scale. Such scales allow for connotative meaning differentiation among individuals who are considered very knowledgeable about the meanings (and context) they are asked to render opinion on (Osgood, 1964).

As questionnaire development from the analysis accomplished in Round 1 was underway, there was an expectation that members of the expert panel would have opportunity to read carefully the summary document provided them. In particular, coming to Round 2 with some background from the representative - but anonymous - comments from individuals in Round 1 was deemed essential to the success of succeeding rounds of the Delphi. In this period of self-guided consideration of individuals’ responses and the summaries of the themes that emerged from the initial free-form exercise, the Round 2 instrument was submitted to the ENREB for approval. This Approval was provided March 28, 2014 which constituted an anticipated amendment to the original research protocol, and Round 2 began immediately with the upload of the questionnaire to FluidSurveys 4.1[®] on April 1, 2014.

Expert Panel Procedures for Round 2

In Round 2, 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 meaning, a number of

items required participants to *justify* their ratings and/or comment upon the item. In some cases, commentary was asked for on the degree to which the wordings presented were representative of their understanding of that item. In addition, there were items brought into the questionnaire that were coming from demonstrated interest that was generated in the Round 1 responses but did not readily have a thematic fit. These included:

- Responding to vision statements from the Science Council of Canada study (1984) and the Pan-Canadian Science Framework (1997) and having an opportunity to assess the present-day relevance of these visions for science education with a view to forecasting to the year 2030;
- Assessing the future role of the Council of Ministers of Education, Canada (CMEC) and formal science education;
- Applying ratings to roles that were identified for a comprehensive list of traditional stakeholders in science education and their relationship to curriculum development;
- Self-assessment of their knowledge about the contents of certain policy statements and frameworks for science education that have been influential over the period 1981 – present, and;
- Self-assessment of the depth to which the Round 1 Summary Report was read prior to completing Round 2 (cf. Figure 14).

Production of Summary Reports with Descriptive Statistics

Once Round 2 was completed online, detailed summary reports were generated to be fed back into the expert panel cohorts. These summaries included descriptive statistics (percentages, mean, median, standard deviation, variance, and interquartile ranges (Q3-Q1)) for each item rated in the questionnaire and associated justification comments. This level of detail is appropriate only to the researcher. In the case of the summaries prepared solely for the expert

panel, only the mean, median, and variance were provided as these are the simplest to show the level of consensus and the degree of clustering around a central tendency. Justification comments that were deemed *representative* either of a notable departure from the consensus position or aligned with consensus were provided to the expert panel. In order for participants to be prepared for the manner in which these statistical summaries would be organized, an interim round brief was prepared and sent to the expert panel ahead of the summary reports once online submission 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 3¹⁰. This procedure for data organization and reporting to the expert panel is well-supported by the literature base in Delphi studies (Hasson, Keeney & McKenna, 2000; Holey et al., 2007; Hsu & Sandford, 2007b; Powell, 2003).

Procedures for Data Analysis in Round 2

For this research study, standard Likert-scales were used predominantly in addition to, on occasion, opportunities to use a semantic differential scale or to respond to text provocations that were brought forward by respondents from Round 1. The literature provides some latitude as to what constitutes consensus positions among an expert panel. For instance, there are Delphi studies that consider values as low as 60% simply being in agreement on an item to others that consider over 80% strong agreement as being necessary. In the only other national-level Delphi conducted in science education with an expert panel (Collins et al., 2001; Osborne et al., 2003), themes that had a mean rating of >3.60 and/or a mode of 5 were considered as strong consensus

¹⁰ This information brief can be viewed in Appendix 'T'.

positions and constituted what would be argued for in matters of curriculum related to the nature of science. For this study, not all items had a direct relationship to the foundations and goals of science curriculum. For those that did have this connection to curriculum the following was developed as a definition of a “positive consensus” position:

- Mean value of >3.80 with a standard deviation < 0.75 ; and/or
- Mode of 5.0 ; and/or
- Interquartile range ≤ 1.00 ; and/or
- Percentage selecting either a ‘4’ or a ‘5’ as a rating $> 70.0\%$.

For the purposes of this study, “negative consensus” is defined as the expert panel being largely opposed to having a favourable position for an item that has been rated, as determined by the following:

- Mean value of < 3.10 with a standard deviation < 0.75 ; and/or
- Mode of ≤ 3.0 ; and/or
- Interquartile range ≤ 1.00 ; and/or
- Percentage selecting either a ‘1’ or a ‘2’ as a rating $> 30.0\%$ and/or the percentage selecting either a ‘4’ or a ‘5’ rating was $< 30.0\%$.

In addition, provision needed to be made for *dissensus* positions in expert panel responses (polarity in rating responses). This is distinct from the negative consensus position just described. In order to identify those instances of item dissensus, the following was developed:

- Mean value clustering near 3.00 with a standard deviation > 1.15 ; and/or
- Bimodal distribution in the modal analysis; and/or
- Interquartile range of >1.00 ; and/or

- Percentage selecting a neutral position (i.e. a '3') was >50.0 %
- Percentage selecting a '4' or a '5' as a rating > 30.0% and those selecting a '1' or a '2' was also > 30.0% occurred simultaneously.

The above systems of analysis – it should be emphasized – were based solely on the use of descriptive statistics. Consideration must be given to the nature of Delphi processes, sample selection, numbers of participants, and how decisions are arrived at by the researcher in defining consensus and dissensus positions. For the purposes of this study, the literature has provided a defensible argument for the scheme just described (Chaney et al., (2009) cited in Shelton (2010); Miller, 2006; Collins et al., 2001; Osborne et al., 2003; Rath & Stoyanoff, 1983; Vernon, 2009).

Round 3 of the Delphi

The third round of the Delphi was the final one conducted in this study. In the literature contesting questionnaire length in the Delphi method from Judd (1971; 1972) we find that, “in studies where participants were required to complete lengthy and detailed questionnaires, and do this iteratively, responses to questions toward the end of the questionnaire period tend to be less informative” (cited in Osborne *et al.*, 2003; p. 700). Participant fatigue was a potential problem that needed close monitoring in this study, but was much more severe in the periods prior to online access to digital instruments. The final round would present to the expert community panel revised summaries, a collection of anonymous and representative comments on the most important themes that have emerged thus far, and the textual and detailed descriptive statistical analyses similar to that provided in Rounds 1 and 2.

At this closing stage, it is recommended that a decision be made as to what constitutes a “level of consensus” among the participants, and stability in the data. In the Osborne *et al.* study,

their definition of consensus was defined as a minimum two-thirds (66.7%) of respondents rating a theme at ≥ 4.00 on the Likert scale. This study uses a benchmark for group consensus at 70.0 % of respondents rating a theme at ≥ 4.00 on the Likert scale. In terms of stability, they defined “stable responses” as no more than a one-third shift in participants’ ratings on items between separate rounds of the Delphi. In an earlier section of this chapter, I outlined what is believed to be a defensible determination for this study as to what constitutes consensus, dissensus, and therefore stability. A significant difficulty in this respect is the apparent arbitrariness of the actual level of response that defines a consensus. As outlined earlier in Chapter 3, some attention was given to designing the study framework such that the Delphi can be both consensus-building and *dissensus-inviting*. Therefore, it was important in the study design to not presuppose equilibrium among the experts whatsoever, and so the study itself becomes simultaneously an exploratory research tool and a celebration of diversity of opinion (Steinert, 2008). In a deliberately consensus/dissensus-oriented design, the semi-quantitative classifications of science education themes developed by the experts themselves serve as the data foundation for later cluster analysis. This introduces into the study a quantitative methodological component that facilitated the analysis and eventual summary of the experts’ input (op.cit., p. 293). In the end, as is typical, the desired outcome of the Delphi approach is to minimize the variance among experts’ opinions. However, as a cautionary tale, minimizing variance is both a statistical matter and a subjective construct that may not always be possible to reconcile, but invites many possibilities.

Expert Panel Procedures for Round 3

In Round 3, as with the previous round, participants were asked to rate the importance, relevance, or influence of (as the case may be) for each of the themes and contributors to Canadian

science education as first seen in Round 2. Again, this was accomplished principally on 5-point Likert scales with ‘5’ being of greatest relevance or importance, etc.. 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 was to consciously remain an outlier external to the emerging consensus. In other cases, optional commentary was asked for (or encouraged) from what had been articulated 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. Just as was done in Round 2, there were items brought into the questionnaire that were coming from new, demonstrated interests that were generated in the Round 2 written responses but may not have readily offered a new or existing thematic fit. These included:

- Responding to statements of K-12 science education objectives from the Science Council of Canada study (1984) and having an opportunity to assess the present-day relevance of these curricular objectives for science education with a view to forecasting to the year 2030; it is noted here that only those participants who had been teachers of science (or still are) responded to this set of objectives;
- Themes which demonstrated the lowest levels of ‘negative consensus’ were eliminated from the Round 3 questionnaire;
- Those having achieved a threshold of > 95.0% consensus from Round 2 were not re-entered into Round 3 (i.e., those that had support from all four consensus criteria with a mean value of >4.20 with a standard deviation <0.60, mode of 5.0, interquartile range <1.00 and percentage selecting either a ‘4’ or a ‘5’ as a rating as > 90.0 %;
- Providing an indication of the professional position (or lens) that had the greatest influence on informing their responses in the study (with over 20 options from which to choose);

- Evaluating their position with respect to two complementary (or competing?) “visions” of science education – VISION I and VISION II (Roberts, 1983; 2007; 2011);

As was done between Round 1 and Round 2, expert panel members were again provided a statistical summary and controlled feedback of textual responses from Round 2 as a feed-in preparation for the final round. Table 4 below provides a sample of the organization and appearance the statistical item summary report with its inclusion of means, medians, and variances as descriptive statistics:

Table 3: Sample Page of Round 2 Theme Summary for Expert Panel.

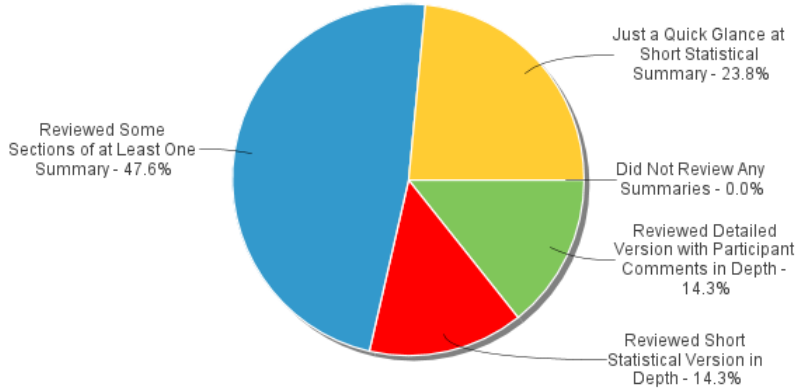
Question 1 - Please rate the level of importance for each of the global trends listed here in terms of your perceptions of their expected level of influence on formal (school) science education in the next 20 years. 'Formal' can include post-secondary education environments.

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Question 1 Science, Technology, Engineering & Mathematics (ST...	3.90	4.00	0.49
Question 1 Integration of Indigenous Perspectives / Knowledge	3.17	3.00	0.87
Question 1 Developing Skills for the 21st Century	4.32	5.00	0.72
Question 1 Science and Education for Sustainability	3.90	4.00	0.62
Question 1 National/International Student Assessments (e.g., ...	3.62	4.00	0.72
Question 1 New Learning Technologies	3.95	4.00	0.63
Question 1 Relevance of Science Education to Students	3.76	4.00	0.87
Question 1 National / International Standards	3.54	4.00	1.00
Question 1 Science Education for Economic Competitiveness	3.56	4.00	1.05
Question 1 Reconceptualizing the Purposes of Science Educatio...	3.36	3.00	1.16
Question 1 Globalization of the International Community	3.49	3.00	0.76

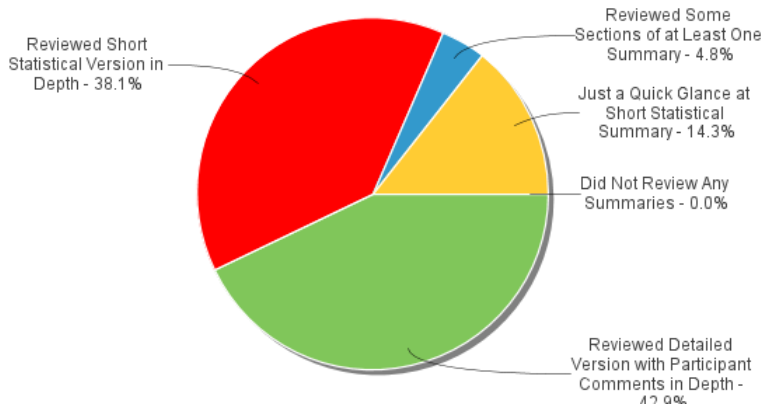
Once more, participants were provided an opportunity to self-assess the depth to which they were able to gain access to and read the analyses provided in between Rounds 2 and 3. In order to provide a manageable opportunity for this, two versions of the Round 2 report were provided to all participants: a longer version which contained all of the commentary in addition to the descriptive statistics and a shorter version which was the statistical summary only. Figure 13 below provides details of their respective self-assessments:

Figure 13: Expert Panel Member Self-Assessments of Review of Round 2 Summary Reports.

COHORT 1



COHORT 2



The final step of the three-round Delphi process was a redirection to an exit page that permitted expert panel members of both cohorts to determine how they wish to be acknowledged for their contributions and how best to disseminate the research results to them either electronically or via surface mail.

Validity and Reliability Plan

Face and content validity issues were discussed in a general way earlier in this methodology chapter in terms of the selection of expert panellists and a field trial via a pilot

phase of the initial online questionnaire. Participants' knowledge about their level of understanding of the Delphi process, the readability and clarity of question content, and freedom of expression were key content validity concerns at the outset of this study. In terms of face validity, the modified Delphi method suggested for this study has the validity attributes of: 1) making use of experts' opinions and commentary based on real contexts; 2) joint consideration of the researcher as among the expert community and the experts themselves in order to foster both the scientific and the social objectives in the study; 3) a combination of face-to-face stages (the semi-structured interviews) and anonymous, asynchronous Delphi stages, and; 4) reliability resting with the participation, involvement, and interactions among authentic experts in real contexts producing the derived quantitative and qualitative feedback that can lead to superior group results (Landeta *et al.*, 2011).

Pilot Delphi Questionnaire Construction and Procedures

Using a technique adapted from that used by Shelton (2010), the Round 1 questionnaire instrument was reviewed in a final-form, web-based platform of FluidSurveys™ by five individuals who were not able to consent to and commit to full participation in the research but offered to review and provide feedback to the researcher. This informal review process of the instrument was an important consideration but did not, in my opinion, supply sufficient conditions for a robust review. For instance, it was apparent that the ability to navigate the online questionnaire included an orientation to or a familiarity with menu-driven items. Perhaps more seriously, the ability of the end-user to fully appreciate what information was being asked for (even if it is personal demographic information) was surprisingly confusing for the reviewers. Shelton (2010) identified circumstances such as clarity of instructions and question validity as

needing improvement in her study before the survey could be distributed for first round delivery to the panel of experts. Feedback collected from the review of the questionnaire in this study similarly revealed several weaknesses in the instrument and recommendations for change. In particular, the demographics data collection component used a number of drop-down menus which proved cumbersome to users. These were modified for simplicity and some menus were dropped altogether prior to the instrument being submitted to the ENREB for protocol approval.

Iterative Delphi Survey of the Expert Panel – Procedures and Interviews

The policy Delphi method is, as stated earlier, an iterative process among an expert panel and has been described as “investigating what does not yet exist” (Skulmoski & Hartman, 2002; p. 2). To maintain panelists’ engagement, it is of importance that the time frame for the entire multi-round process - and the span of time between successive rounds - be kept as short as possible. Consistent with the graduate research analysis done by Skulmoski, Hartman and Krahn (2007) - the latter two authors working out of the University of Calgary - maintaining the enthusiasm and engagement of the expert panel subsisted in large part with keeping the intensity constant and the structure of the rounds coherent, organized, and predictable. This was accomplished, in part, through a combination of creative adaptation to a particular context or situation, modes of interaction that were interesting to participants, methodological consistency between rounds with an audit trail, and a balance between validity and innovation in the techniques. The extensive bibliography of quite wide-ranging dissertation topics as Delphi studies included in their article provided brief research descriptions, numbers of rounds in each study, and sample size including its degree of heterogeneity or homogeneity. For those using

Delphi at the level of graduate research, this useful list demonstrated how comprehensive their treatment was and provided these recommended focus areas as to procedures:

- Methodological choices such as a qualitative, quantitative or mixed methods approach;
- Initial question degree of focus whether it be broad or narrowly focused;
- Expertise criteria such as technical knowledge and experience, capacity and willingness to participate, sufficient time, and communication skills;
- Number of participants in the heterogeneous or homogeneous sample;
- Number of Delphi rounds varying from one to six with three as ideal;
- Mode of interaction such as through email, online surveys or groupware;
- Methodological rigor and a research audit trail;
- Results analysis;
- Further verification through triangulation or with another sample, and;
- Defense and publishing of the results. (Skulmoski, Hartman & Krahn, 2007; p.1).

At the conclusion of the three Delphi rounds and their questionnaires, five semi-structured interviews among expert panel members were conducted from both COHORT 1 and COHORT 2. Each interview was designed to clarify particular, representative positions from among the major themes in the study. These interviewees were provided an opportunity for member checks to determine what from among their comments could be classified as data and provided the study with some measure of triangulation of the results. Of the five interviews, four were devoted to further clarification of “substance” positions from the themes while one looked more closely at the Delphi process *as methodology* in gathering expert opinion. A comparison/contrast with the deliberative inquiry techniques first developed by Orpwood (1981) was the rationale behind this one interview which was conducted with a participant who was on the research team of the Science Council of Canada report completed in 1984.

Summary of the Methodology

Historically, the Delphi method has been used by researchers as an iterative process to collect expert opinion and analysis in order to achieve consensus opinion and/or positions in relation to a complex issue that would otherwise be difficult to obtain through more direct, deliberative and face-to-face interaction (Clayton, 1997). This chapter has addressed: the purpose of the research; the research questions; research design and methodology using development of a modified policy Delphi technique; instrumentation and procedures for questionnaires and semi-structured interviews of the expert panel; criteria and cautions for selection of the expert panel; a validity and reliability plan, and; specific methods of data collection and analysis. As an important reminder, this study made use of expert opinion in science education from diversity of viewpoints from across Canada comprising two distinct, asynchronous cohorts of discipline-based, special-interest based, or subject-area specialists – an expert panel - for the purposes of establishing benchmarks and points of departure for more clearly appreciating how current trends nationally and internationally may influence – or be influenced by - the foundations and goals of future science education in Canada post-2015 and forecasting to a future which is difficult to know but can be provisionally envisioned through the Delphi experience.

Chapter 5: Data Collection and Analysis I

This chapter addresses and examines in a general manner the data collected over the three rounds of the modified Delphi study. The chapter concludes with a comprehensive tabulation of consensus levels across the two cohorts in the study for the 47 themes which emerged from the Round 1 coding. A succeeding chapter will address the results of the three Delphi rounds grouped by the research questions. This way, provision is made for those who are seeking a ‘meta-synthesis’ across the four open-ended seed questions and how these informed subsequent rounds of the Delphi. Those interested in the finer stratigraphy of the data in terms of how the research questions are addressed will want to satisfy that interest with further reading. The study was implemented over a 17-week period with a panel of experts differentiated across two distinct cohorts demarcated by the era in which the majority of their contributions have been professionally. The methodology chapter outlines 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”. 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.*

Expert Panel Participation Synopsis

In this research (N = 130) individuals were selected for invitation into the study by virtue of meeting the criteria as outlined in the methodology. Ultimately, (N = 54) agreed to participate in Round 1 and completed Informed Consent letters. Though voluntary, candidate participants formed a representative, purposeful sample to collaborate online as an expert panel and were from among 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 (selected from all grade levels K-12 where the recipient's biography indicated a

preference for the teaching of science or an actual science teaching appointment as a specialist);

- The Council of Canadian Academies' Expert Panels working on current science-related 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 at that time;
- Deans of Canadian university medical schools;
- Teacher-educators in faculties of education in Canadian college or university settings, and;
- A randomized selection from among Tier 1 and Tier 2 Canada Research Chairs in the natural sciences, science education, and engineering generally representative of dispersion in Canada (N = 830 in random sample where $N_{(\text{selected})} = 20$).

Round 1 responses (N = 51) provided a rate of response which is well within optimal expectations in a Delphi. Of the 51 who were invited to continue with Round 2, there were (N = 46) completed responses. Round 3 had an effective response rate with 42 of the 46 providing completed questionnaires. The literature review confirmed that on most occasions it is difficult to maintain high response rates over multiple rounds of a Delphi and these rates decrease markedly in studies having ≥ 4 rounds. With this study demonstrating $\geq 90\%$ response rates over three rounds, the expert panel's participation far exceeding expectations and was much greater than the approximate value of $\geq 70\%$ per round rate identified by Hasson, Keeney & McKenna (2000), Hasson & Keeney (2011) and Keeney & Hasson (2011b). Table 5 outlines the pattern of expert panel response rates over the duration of the study.

Table 4:
Expert Panel Participation Rates in the Delphi Study.

Delphi Round	Expert Panel (N)	Expert Panel Completed	Response Rate (%)
Invitation Phase	130	54	41.5%
Pre-Round I			
I	54	51	94.4%
II	51	46	90.2%
III	46	42	91.3%
Exit Round	42	41	97.6%

The total range of response length to each of the four questions was quite 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, opinions, and 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. The coding was conducted in the following manner:

- 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 to 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 NVivo 10™, and (4) matrix coding NVivo 10™ using two or more similar concepts, explanatory ideas, or phrases (as outlined in (c) above).

These five coding procedures became the basis for identifying the *themes* in the data.

Round 1 Data Analysis and Results

Word Frequency Analyses

Conducting word frequency analyses was the first stage of coding the data using NVivo 10™ Computer Assisted Qualitative Data Analysis Software (CAQDAS). This was an important first step in assessing the depth of the stratigraphy contained in this large volume of text data. Initially, the 100 most frequently appearing words of ≥ 5 characters across all 51 transcripts were identified. After filtering out all keywords that appeared in the seed questions, this word

frequency query was further reduced to the 50 most frequently occurring words. All words that had a frequency weighted percentage exceeding 0.37 and/or a word count across all participants of ≥ 25 were logged into the NVivo 10™ project file as a query. The following figures provide pictorial samples of the word frequency analyses across each of the four seed questions from Round 1.¹¹

¹¹ In order to view all word frequency analyses, consult Appendix ‘G’.

Figure 11: Word frequency analysis – Question 1 – Global Trends.

Word Frequency Analysis Round 1 Question 1

science	issues	technology	trend	world	information	related	systems	even	years	social	believe	disciplines	nature	many		
					become	understanding	impact	provide	design	society	good	people	time	activities		
	learning	cohort	based	development			canada	skills	questions	also	content	experience	require	knowledge		
			work	research	sustainability	make			address	future	interest	current	better	resources	high	
education	students	global			curriculum	scientific	like	engage	energy	teachers	support	traditional	evidence	results	used	
			change	important			part	male								
	need				point	focus			national	classroom	area	include	perspective	great	ontario	
		increasingly	countries	well			political	problem	much	climate	female	real	productio	space	movement	
					economic	access										
							continue	place	order	example	must	human	response	perhaps	assess	environ

Figure 12: Word frequency analysis – Question 2 – Foundations and Goals in Science Education.

Word Frequency Analysis Round 1 Question 2 Foundations and Goals of the Science Curriculum

science	students	knowledge	thinking	issues	canada	development	process	female	evidence	study	possible	include	opportunities		
			technology	using	engage	basic	society	problems	community	models	value	research	contribution	place	
		understanding						related	content	canadian	opinion	generation	based	approach	physics
	cohort		learning	literacy	natural	systems	skills		classroom	working	citizens	curiosity	often	within	taking
		world			information	needs	response	solving	people	apply	current	becomes	successful	build	order
education			important	goals				career	focus	inquiry	decisions	principal	answer	change	context
	scientific				continue	critical	teachers	interest	design	ideas	application	social	rather	specific	background
		foundations	questions	lives	provide	curriculum	concepts	level	identify	cultural	challenge	address	first	essential	promote
													experiences	future	scientists

Figure 13: Word frequency analysis – Question 3 – Barriers and Opportunities for a National Vision for Science Education.

Word frequency analysis - Question 3 - Barriers and Opportunities for a National Vision for Science Education

education	national	vision	canadian	support	federal	knowledge	female	territories	include	government	across	jurisdictions	people		
			world	students	barrier	needs	different	current	practices	research	common	indigenous	rights	example	
		canada													
	cohort				development	change	collaboration	institutions	individual	areas	decisions	related	create	responsibility	
			issues	level					share	direction	priorities	programs	quebec	question	implement
		political			framework	understanding	learning	standardized	years	address	perspective	better	diversity	however	alignment
science			provincial	provide			country	interested							
	provinces				system	teachers			project	process	grade	university	formalized	think	basic
		curriculum					place	economic				assessment	challenge	scientific	remain
			opportunities	believe			resources	important	ministers	study	evidence				
					based	course						declaration	curricula	results	local
									within	perhaps	moving			content	
												together	often		

Figure14: Word frequency analysis – Question 4 – Canadian Approaches to Science Education.

Word frequency analysis - Question 4 - Canadian Approaches to Science Education

science	cohort	learning	world	different	examples	sustainability	possible	understand	however	scientific	level	response	knowledge		
								information	particularly	provincial	compared	global	process	decisions	
			students	international	research	curriculum	context	areas	technology	practice	curricula	problems	resources	universal	
	canadian	canada			question	political	opportunities	challenges	address	multicultural	society	system	ensure	individual	perspective
			countries	based		aboriginal	values	similar	allow	people	found	generatio	materials	engaged	inclusive
education				think	national		study	might	character	within	goals	adopt	geograph	social	current
	approach	unique			female	develop	share	create	include	become	rather	knowing	years	climate	future
			issues	place	important	needs	environment	skills	jurisdiction	results	whether	solving	regional	often	teach
											common	natural	distinguish	provide	

The next set of queries in NVivo 10™ involved textual associations of predominant keywords into word clusters that could then be the subjects of a new set of associations that would comprise the “node classifications”. Such 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 emergent node classifications across the first two of the four seed questions (Questions 1 and 2). It is important to note that at this early stage of querying the textual data, it was premature to determine with certainty what the major themes would eventually become (what follows was considered provisional based only on word frequencies).

Node Classifications – Identifying Global Trends Affecting Science Education

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

Node Classifications – Identifying 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
- Literacy in Science-Related Issues and Scientific Literacy
- Science for Economic Competitiveness

Node Classification Samples

The following three sample figures demonstrate how the word frequency analyses can be developed into “trees” which provide some context through linking words and phrases. These linking words and phrases on either side of the search term assisted in providing for richer contextual cues that ultimately guided the detailed reflexive and iterative coding. For instance, if one looks at the word tree related to the use of the word “skills”, it is apparent that there is diversity among participants as to what is meant by the term ‘skills’ or how skills may be operationally defined.

Figure 15: Word frequency analysis tree – Science for Sustainability and Global Citizenship.

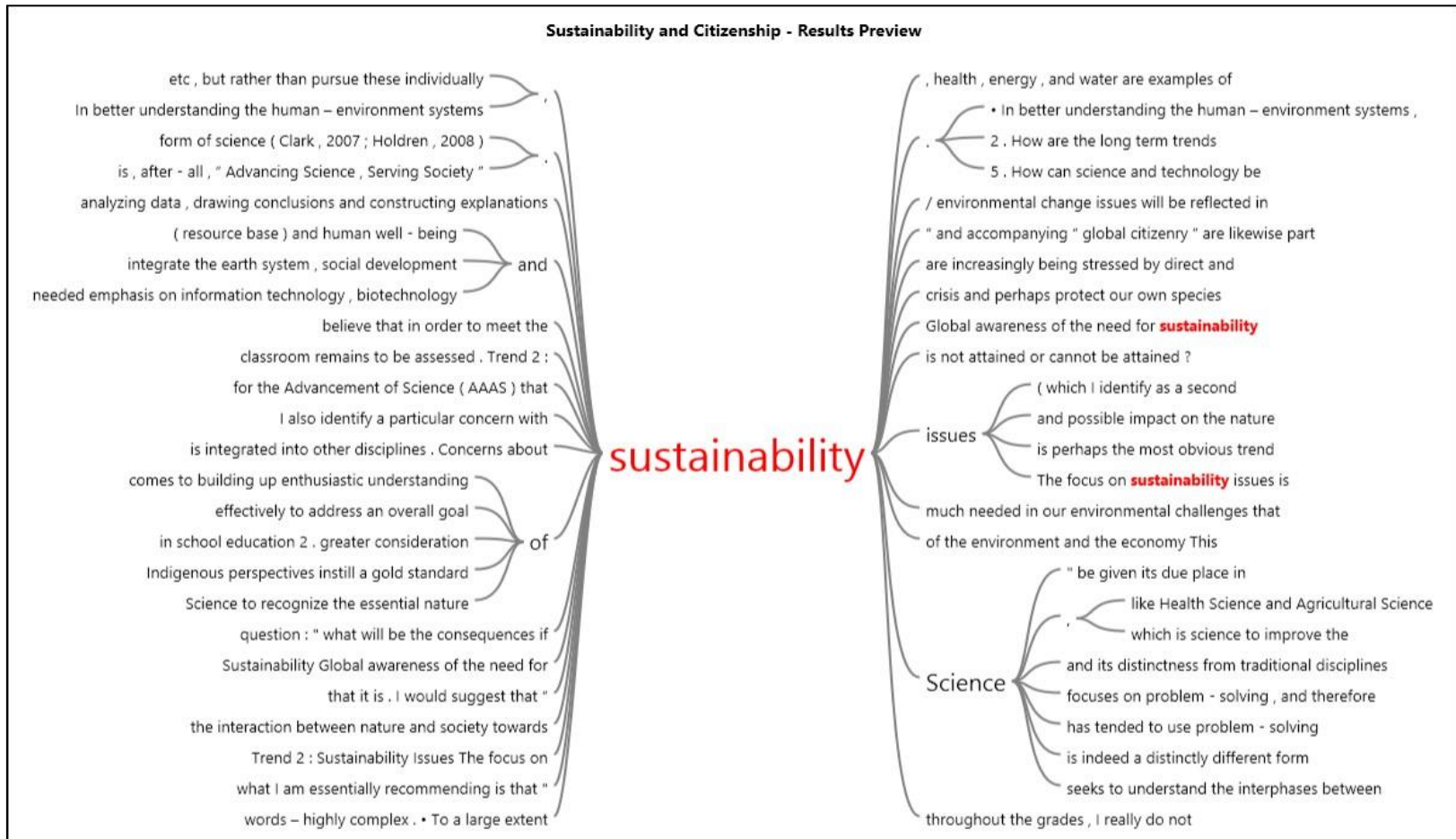


Figure 16: Word frequency analysis tree – Science, Technology, Engineering and Mathematics (STEM).

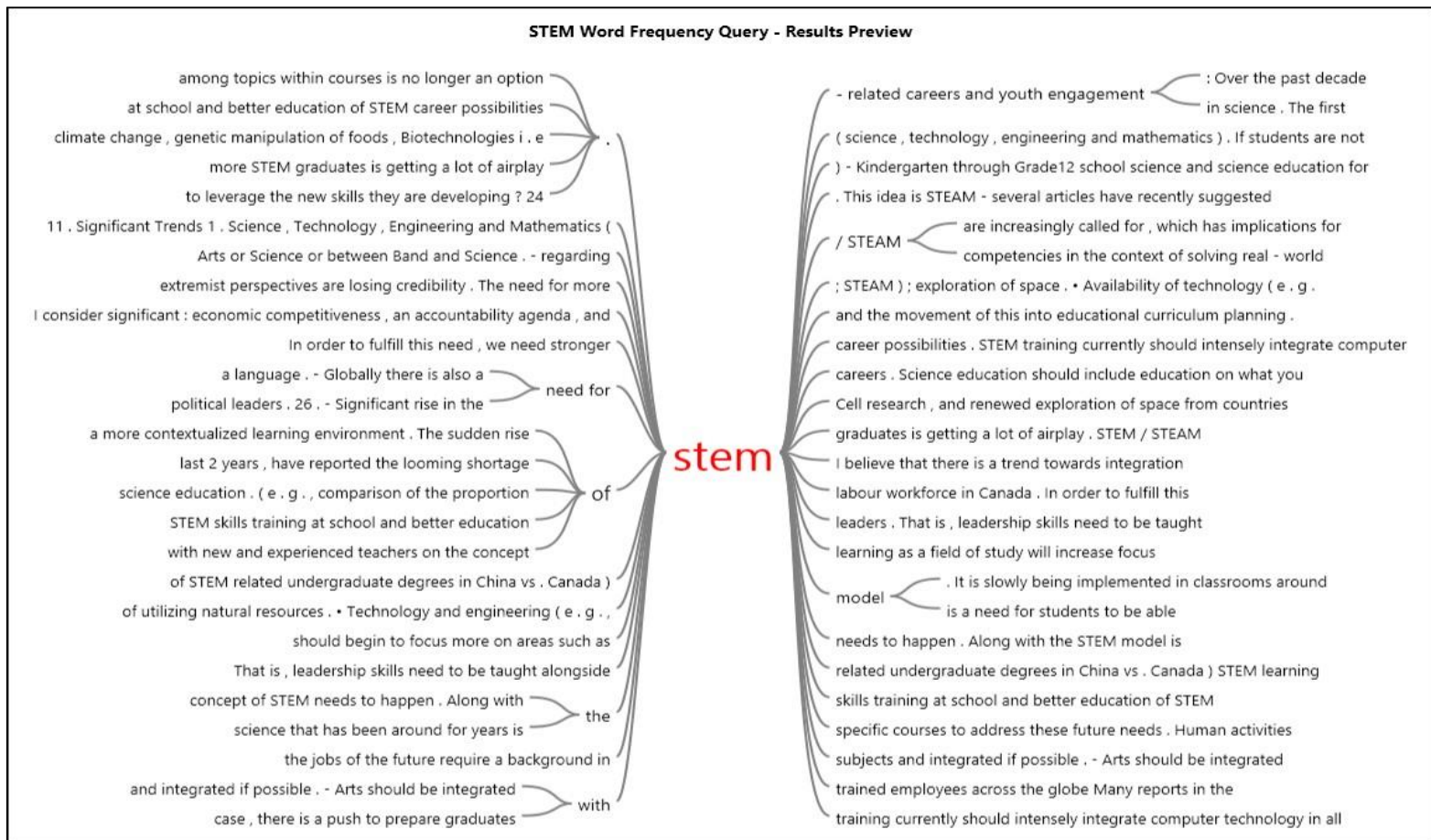
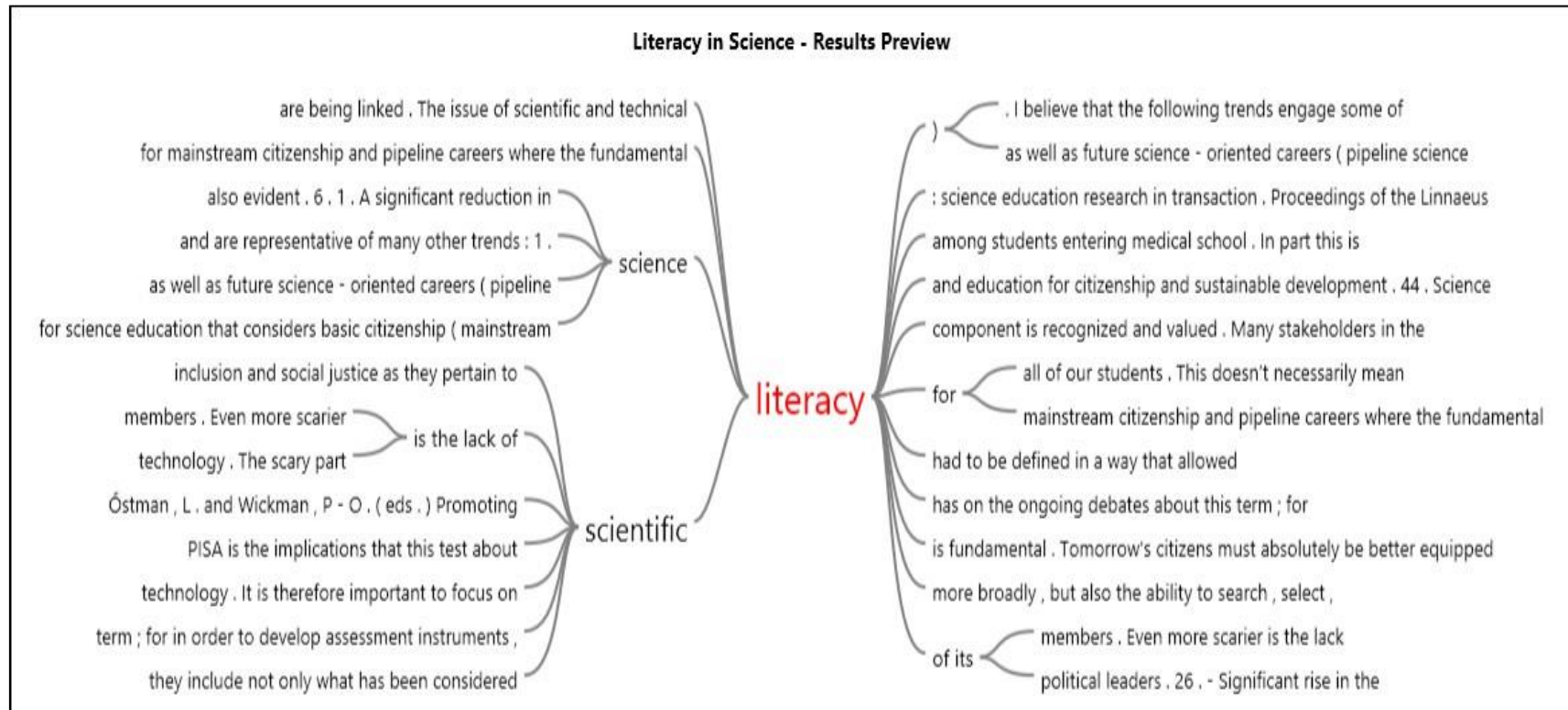


Figure 17: Word frequency analysis tree – Scientific Literacy.



As was outlined in Chapter 4, the next phase of data analysis included a 4-week span of time devoted to detailed coding using these practices: (1) Any node categories containing a minimum of two sources (a “source” is an individual respondent) and two references (a “reference” is a codeable item) were then provided a second pass by the researcher for re-coding; (2) this second pass involved coding of individual responses across each of the two cohorts separately and another coding with all responses collated into to a single text document (combined cohorts) – one document for each of the four Round 1 seed questions; (3) 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): (a) individual participant responses, (b) aggregated responses within a cohort, (c) auto-coded responses from text analyses in NVivo 10™, and (d) matrix coding in NVivo 10™ using two or more similar concepts, explanatory ideas, or phrases.

What the above coding procedures uncovered were a significant number of themes emergent from the writing of responses in Round 1. Table 6 provides an exhaustive list of the coded nodes which provided the basis for the themes to be further explored by the expert panel in Rounds 2 and 3 of the Delphi.

Table 5: Theme Nodes Derived from Reflexive Coding of Round 1 Responses¹²

<i>THEME NAME</i>	<i>Sources</i>	<i>References</i>
<i>Canadian Approaches to Science Education</i>	41	52
<i>Canadian Landscape</i>	10	13
<i>Canadian Sovereignty and Influence</i>	5	6
<i>Complex Systems and Complexity Sciences</i>	1	1
<i>Cultural Identity & Multiculturalism</i>	2	3
<i>Education for Sustainability</i>	6	7
<i>Graduate Education</i>	2	3
<i>Indigenous Knowledge</i>	6	6
<i>International Collaboration</i>	3	6
<i>Universality of Scientific Approaches</i>	6	7
<i>Content Area Knowledge in Science Education</i>	91	145
<i>Biosciences</i>	2	2
<i>Health Sciences</i>	2	3
<i>Space Sciences and Astronomy</i>	2	3
<i>Sustainability Sciences</i>	14	25
<i>Geosphere Interactions</i>	15	25
<i>Climate Change Sciences</i>	11	11
<i>Interacting Systems</i>	9	23
<i>Complex Systems</i>	8	8
<i>Systems Thinking</i>	3	5
<i>Environment and Biosphere</i>	7	11
<i>Biodiversity</i>	1	2
<i>Ecosystems Services</i>	5	10
<i>Geological Systems</i>	1	1
<i>Anthropogenic Interactions</i>	11	16
<i>Global Trends Affecting Science Education to 2030</i>	679	1323
<i>(STEM) Science Technology Engineering and Mathematics</i>	25	48
<i>STEAM - Science Technology Engineering Arts & Maths</i>	4	5
<i>STEM Model Standards</i>	1	1
<i>21st Century Skills</i>	38	87
<i>Common Core Standards Models</i>	2	4
<i>Competency-based Learning</i>	4	5
<i>Critical Thinking</i>	10	11
<i>Information Access and Communication</i>	7	7
<i>Learning Technologies</i>	32	53
<i>School to Work Transition</i>	3	5

¹² Note: A “source” represents an individual response coded at that node; “references” are the number of times that coding was tagged in all of the sources. This list is exhaustive and includes all coded nodes from NVivo™.

<i>Global Societal Change</i>	19	37
<i>Citizen Science Crowd Sourced Wisdom</i>	9	11
<i>Equity Issues</i>	2	2
<i>Serious Gaming</i>	1	1
<i>Underrepresented Groups</i>	9	9
<i>Web 2.0 Technologies</i>	6	6
<i>Globalization in Education</i>	41	188
<i>Economic Competitiveness</i>	47	76
<i>Global Learning and International Science Education</i>	17	29
<i>International Common Standards</i>	5	8
<i>Neo Liberalism</i>	12	40
<i>Accountability in Education</i>	17	29
<i>Outcomes and Standards Based Education</i>	5	5
<i>Next Generation Science Standards</i>	2	3
<i>Specialised Science and Math Schools</i>	3	3
<i>TIMSS PISA PCAP Assessments</i>	13	19
<i>Indigenous Knowledge and Perspectives</i>	19	42
<i>Culturally Responsive Science Teaching</i>	17	24
<i>Place Based Approaches</i>	4	5
<i>National Cultural and Personal Security</i>	6	6
<i>Global and Regional Food Security</i>	2	3
<i>New Technologies in Society</i>	26	71
<i>New Technologies in the Classroom</i>	27	71
<i>Learning Technologies</i>	36	66
<i>Massive Open Option Courses (MOOC Platforms)</i>	3	4
<i>Re-conceptualizing of Science Education</i>	17	22
<i>Inquiry Based Learning</i>	8	9
<i>Constructivist Pedagogies</i>	1	2
<i>Interdisciplinary Science Teaching and Learning</i>	5	7
<i>Science and Social Issues</i>	4	4
<i>Play Based Learning</i>	4	5
<i>Problem-Based Learning</i>	31	37
<i>Relevance of Science Education for Students</i>	39	84
<i>Student Engagement in Science</i>	22	24
<i>Science Education Silo Effects</i>	10	13
<i>Sustainability Sciences</i>	24	74
<i>Education for Sustainability</i>	31	44
<i>Sustainable Development</i>	16	21
<i>Foundations of Science Education to 2030</i>	226	323
<i>Applications of Science</i>	11	12
<i>Education for Sustainability</i>	28	48
<i>Barriers and Alternatives</i>	2	6
<i>Environmental Education</i>	7	8
<i>Global Citizenship</i>	19	26
<i>National Cultural and Personal Security</i>	6	6
<i>Global and Regional Food Security</i>	2	3
<i>Social Critique and Social Change</i>	4	5
<i>History and Philosophy of Science</i>	2	2
<i>Interacting Systems</i>	9	23
<i>Complex Systems</i>	8	8
<i>Systems Thinking</i>	3	5
<i>Learning Environments</i>	8	10
<i>Nature of Science</i>	17	23
<i>Outcomes and Standards</i>	3	3

<i>Science and Technology Interactions</i>	14	18
<i>Scientific Knowledge</i>	6	6
<i>Scientific Skills</i>	17	33
<i>Argumentation in Science</i>	3	3
<i>Barriers</i>	6	8
<i>Engineering and Design Processes</i>	2	3
<i>STSE Literacy</i>	24	34
<i>Barriers to STSE Literacy</i>	7	8
<i>Social Justice Issues</i>	2	3
<i>Socio Scientific Issues SSI</i>	10	11
<i>Teacher Education and Preparation</i>	3	5
<i>Contextualised Science Teaching</i>	3	3
<i>Goals of Science Education to 2030</i>	175	220
<i>Economic Competitiveness</i>	9	10
<i>Personal Development</i>	16	24
<i>Character Development</i>	3	3
<i>Life-Long Learning</i>	10	10
<i>Science & Technology as Career</i>	22	33
<i>Barriers to STEM Careers</i>	9	10
<i>Economic Competitiveness</i>	9	10
<i>Innovation</i>	4	4
<i>Scientific Literacy</i>	26	32
<i>Attributes and Characteristics</i>	8	12
<i>Media Literacy in Science</i>	3	4
<i>Scientific Knowledge and Understanding</i>	14	16
<i>Sustainable Society</i>	15	22
<i>Citizenship</i>	12	14
<i>Understanding of Human Impact</i>	9	9
<i>Human Health and Well-Being</i>	6	7
<i>National Vision for Science Education to 2030</i>	254	477
<i>Barriers to a National Vision</i>	36	103
<i>CMEC</i>	5	8
<i>Constitutional Effects</i>	8	9
<i>Diversity in Education</i>	8	13
<i>Linguistic Barriers</i>	3	4
<i>Funding Issues</i>	1	1
<i>Political and Electoral System Effects</i>	15	19
<i>Stakeholder Influences</i>	9	10
<i>Insiders in Curriculum</i>	14	18
<i>Outsiders in Curriculum</i>	10	6
<i>The Canadian Context</i>	34	98
<i>CMEC Initiatives</i>	12	14
<i>Communities and Cultures</i>	4	4
<i>FNMI Perspectives</i>	4	5
<i>National Curriculum Alignment</i>	1	3
<i>National Standards</i>	3	15
<i>Pan Canadian Science Project Legacy</i>	13	1
<i>Practice Informed by Research</i>	1	83
<i>STEM Model Standards</i>	1	3
<i>Opportunities for a National Vision</i>	31	5

<i>CMEC</i>	3	7
<i>Diversity in Education</i>	4	7
<i>Federal Leadership</i>	7	3
<i>Globalising Influences</i>	6	14
<i>National Curriculum Alignment</i>	2	6
<i>Science Council of Canada Study</i>	2	9
<i>Stakeholder Influences</i>	12	3
<i>Standardised Assessments</i>	3	3
<i>Technologies and Networks</i>	2	3

Emergence of Themes in Round 1

The Delphi Round 1 had asked the expert panel to offer written responses to four, open-ended seed questions which (unknown to the participants) were closely tied to the research questions. Succeeding chapters will examine each research question across all three rounds to provide substantial depth to treatment of the data. As a result of the comprehensive reflexive and iterative coding techniques developed specifically for this study, and grounded in techniques that are now becoming well-established in the literature of qualitative mixed-methods research with the assistance of CAQDAS (Bazeley, 2002; 2003; 2006; 2009; Bazeley & Jackson, 2013; Corbin & Strauss, 2008), the principal themes that were provided to the study by the expert panel's contributions were developed into the Round 2 instrument. In all, the expert panel was requested to provide ratings as to the importance of 47 themes which were assembled into items that were grouped in accordance with connections to the research questions. These thematic cluster groupings for the Round 2 instrument were as follows:

Global Trends Affecting Future Science Education (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 (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
6. Scientific Oriented Skills
7. Scientific Knowledge

The Goals of Canadian Science Education (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 Development
6. Life-Long Learning
7. Contribute to Human Health and Well-Being
8. Training of Future Scientists
9. Develop a Deep Sense of Wonder and Curiosity
10. Pursue Progressively Higher Levels of Study
11. Sustaining Earth's Systems

Opportunities and Barriers to a National Vision for Science Education (7 themes)

1. Voices of Indigenous Peoples
2. Cultural Diversity
3. Linguistic Diversity
4. Provincial Electoral Cycles
5. Federal Electoral Cycles
6. Control of Curriculum by Provincial Ministries of Education
7. Physical Geography

A Canadian Approach to Science Education (11 themes)

1. Canada as a Circumpolar Nation
2. Indigenous Ways of Knowing
3. Issues of Gender
4. Issues of Human Rights
5. Regional Priorities
6. Relationships with Trading Partners
7. International Student Collaborations
8. Science Education for a Democratic Society
9. Career Specializations in the Sciences
10. Equity of Opportunity in the Sciences
11. Science Education for a Sustainable Future

Summarizing the Themes from Round 1

Once the Delphi process had reached the preparation stage for Round 2, it was necessary to take the principal themes (above) from the Round 1 responses which were identified through the coding procedures and prepare syntheses of the most representative ones. Descriptions of these themes were delivered back to the participants as part of the controlled feedback which is a staple of the Delphi method. It is up to the researcher to determine what the controlled feedback will consist of. For instance, in this study, the feedback from Round 1 did not include complete transcripts of each participants' contributions as this was deemed excessive. Each member of the expert panel did receive a transcript of their personal responses to the Round 1 questions along with a summary document providing the evidential basis of the principal themes. Important in the theme summary document were the following: (a) provisional large-scale theme titles, (b) a brief synopsis of the *justification for emergence* for the theme including representative concepts tagged with alpha-numeric ID codes of participants, and (3) direct quotations (again with attached ID codes) from participants who

provided representative and notable definition(s) to the theme. The methodology chapter (Chapter 4) provides a sample page of the summary report (see Figure 12, page 156).

Emergent Themes

In this section, each of the representative themes are presented from the responses from Question 1 and Question 2 of the Round 1 questionnaire. The themes are ordered hierarchically in accordance with the number of times that theme was addressed explicitly by respondents in Round 1. That is, grouped according to raw *impact factor* values. Impact factor is determined from the reflexive coding procedures and is simply the ratio of *references:sources*. To illustrate, if a theme emerged in the coding with 48 references from 25 sources the impact factor would be 1.92 (Juniper et al., 1997). Consideration, then, must be granted to situations where small numbers of participants (sources) generate large numbers of references which would artificially inflate impact factors. To identify these instances, a second impact factor – *high individual impact factor* – was also developed and calculated. The high individual impact factor was determined by looking at the overall number of references to a particular theme which were coded and identify instances where individual members of the expert panel contributed multiple references to a single theme. By way of clarification, an impact factor ≥ 0.05 implies that at least 5% of references to that theme have come directly from a single contributor. Though this may seem a very small value

we have to bear in mind that (N = 51) for Round 1 and the coding on occasion produced in excess of 75 unique references to one theme.

If the individual impact factor was ≥ 0.05 for a theme, this was deemed the minimum qualification for being cited directly in the summary fed back to the panel between Rounds 1 and 2. For each theme, the summary offered a brief outline of its justification for emergence and included representative statements of two kinds: 1) those taken from expert panel members having a high individual impact factor in their remarks on the theme, and; 2) remarks which were representative of arguments using compelling language or the bringing forth of unique perspectives on the themes. This was done intentionally to decrease to some extent the selection bias of remarks having significant effect on the development of the themes solely from the impact factors. It was felt by the researcher that certain minority opinions (or positions) would be lost if some measure of discretion was in effect.

In the synopsis of the themes presented below, some of the themes have been re-grouped to represent the manner in which these were presented to participants during the between-round feedback period. This was done to decrease the reading load on participants prior to Round 2 since 47 separate sets of commentary would have been debilitating to many members of the panel. This collapsing of themes also presaged later rounds when participants actually recommended that there was significant overlap among certain themes and that it would be preferable to consider a re-grouping. The list that follows provides

details of which themes underwent a re-grouping for the sake of the participant summary following Round 1:

- a. In the **Global Trends Affecting the Future of Science Education**, Globalization of the International Community and Neo-Liberal Values includes: National/International Student Assessments (e.g., PISA, TIMMS, PCAP); National / International Science Standards, and; Science Education for Economic Competitiveness.
- b. In the **Foundations of Canadian Science Curriculum**, Science Education for Global Citizenship and Science Education for Sustainability are combined into a single theme; Scientific Knowledge was set aside and not included in the summary report as its coding demonstrated too much variety in the interpretation of what 'knowledge' means to curriculum, teaching, and learning.
- c. In the **Goals of Canadian Science Education**, the new theme of Scientific Literacy, Personal Development and Life-Long Learning includes: Literacy in Science-Related Issues; Personal Development, Training of Future Scientists, Pursue Progressively Higher Levels of Study, Develop a Deep Sense of Wonder and Curiosity, and Life-Long Learning; the new theme of Science for Career-Building and Economic Competitiveness includes: Career-Building for a Technological Society and Economic Competitiveness.; the new theme of Science Education for a Sustainable Society now subsumes: Contribute to Human Health and Well-Being, Sustaining Earth's Systems.
- d. In the **Opportunities and Barriers to a National Vision for Science Education**, ALL seven of the themes generated from the coding were developed under the new theme of The Canadian Context. Impact factors are determined for this theme but solely for the purpose of gauging response rates. Hence, the reader will see an $N = x$.
- e. In the **A Canadian Approach to Science Education**, all eleven themes generated from the coding were developed under the new theme of Canada and the International Community. Impact factors are determined for this theme but solely for the purpose of gauging response rates. Hence, the reader will see an $N = x$.

Global Trends Affecting the Future of Science Education

Globalization of the International Community and Neo-Liberal Values (Impact Factor = 4.58)

Justification for Emergence¹³

This theme, for the purposes of defining what has emerged among the study participants, can be captured and characterised by sub-themes such as: science education for economic competitiveness; global learning and international reach of science education; the movement towards international common science standards; the founding of specialised schools of STEM, the American *Next Generation Science Standards*; and national and international assessments such as PCAP, TIMSS, PIRLS, and PISA.¹⁴ Among the participants in the study, virtually all contributors had a perspective on “globalising” influences in science education. The sub-themes just listed include most of the prevailing interest areas. The effects of accountability demands in educational systems worldwide is deemed to be a potentially major influence on the nature of science education. For instance, the ‘focus on assessment for accountability’ could be viewed as antithetical to the three decades of effort – especially sourced in Canada – of the Science, Technology, Society and Environment (STSE) perspectives (1047PB). The links among standardised test results, international stature, and perceived

¹³ The alphanumeric codes (e.g., 1111XY) refer to participant individuals in the study; these selections are not necessarily verbatim quotations but are representations of text that provide insights into defining the theme.

¹⁴ Acronyms: STEM (Science, Technology, Engineering and Mathematics); PCAP (Pan Canadian Assessment Program); TIMSS (Trends in International Mathematics and Science Study); PIRLS (Progress in International Reading Literacy Study); PISA (Programme for International Student Assessment).

future economic competitiveness and prosperity are taken as increasingly tightly linked and viewed collectively. Indeed, these influences are thought to put the ‘spotlight on science education’ (1067PB | 1098PS).

With the rapid rise of possibilities among internationally networked educational institutions and networked students, the possibilities seem endless for collaboration as a nascent research community. ‘Significantly increased numbers of youth working together in a research community’ (2009ST) raises prospects of a ‘changed focus of scientific research’ (2014ST) that is oriented towards commercialization and ‘economic advantage in a global marketplace’ (2054TE). That ‘growth of economic globalisation and the attendant growth of the economic impact of science and technology (S&T) could lead to increased importance of education for S&T; and, the constraints imposed by the reliability (or not) of assessment measures at the international, national, and local scales’ (2085PE).

Representative Statements¹⁵

1) In an increasingly globalized world that is interdependent and competitive in terms of both economic productivity and educational attainment, there has been a steady movement toward standards-based science education.¹⁶

2) L'école doit se développer l'esprit de collaboration et favoriser le réseautage. La classe devra être délocalisée et entrer en contact avec des élèves

¹⁵ These statements from participants are simultaneously representative and verbatim. All references to literature were cited by participants in their responses and are not self-citations or those of the author.

¹⁶ G.E. DeBoer (2011). The globalization of science education. *Journal of Research in Science Teaching*. Vol. 48(6), 567-591.

d'autres pays pour partager les réalités vécues. The school must develop a spirit of collaboration and promote networking. The classroom will continually relocate and contact with students from other countries will permit the sharing of their lived realities. (2014TE)

3) The greatest threat from “global modernity” is the steady erosion of the life-support systems of the planet by an increasingly non-sustainable, selectively globalised society. (2067PE).

4) A major trend of science is directed toward the commercialization of science and increased focus upon application of science toward economic benefits for a country. (2080TE)

5) Thirty years ago, when the Science Council of Canada published *Science for Every Student: Educating Canadians for Tomorrow's World*, the state of science education in Canada relative to other countries was not considered. Now, the interest in studies such as TIMSS, PISA, and research on science education around the world reflects growing awareness that Canada (and by implication its provinces and territories) lives in an increasingly competitive global society. (2085PE)

6) A “common core” curricula for all subjects. Development of nation-wide standards-based curricula focused on core concepts and learning progressions; input from non-curriculum specialists will have increased influences. (2054TE)

Science and Education for Sustainability – The Sustainability Sciences (Impact Factor = 3.08)

Justification for Emergence

The emergence of a novel academic discipline about a decade ago which can be described as the ‘sustainability sciences’¹⁷ enters the discourse among the study’s participants. This field had rather a “birthing experience” at the world congress “Challenges of a Changing Earth 2001” in Amsterdam which was organized by the International Council for Science (ICSU), the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change and the World Climate Research Programme (WCRP). By way of a definition, the field reflects a desire to give the generalities and broad-based approaches of “sustainability” a stronger analytic and scientific underpinning as it:

“... brings together scholarship and practice, global and local perspectives from north and south, and disciplines across the natural and social sciences, engineering, and medicine as it can be usefully thought of as “neither ‘basic’ nor ‘applied’” research but as a field defined by the problems it addresses rather than by the disciplines it employs; it serves the need for advancing both knowledge and action by creating a dynamic bridge between the two.”¹⁸

¹⁷ Kates, R.; Clark, W.; Corell, R.; Hall, J.; Jaeger, C.; et al. (2001). "Sustainability science". *Science* **292** (5517): 641–642.

¹⁸ Clark, W.C. (2007). Sustainability Science: A room of its own. *Proceedings of the National Academy of Science* 104: 1737-1738; published online on February 6, 2007, 10.1073/pnas.0611291104.

Sustainability sciences is responding to ‘global trends in education for sustainability which may grow over the next 15 years directing science education to consider economic, societal and political factors in science’ (1085ME). There exists the viewpoint that globalization and its influences – particularly from the economic and environmental foci – will generate ‘critical issues for consideration in formal education’ (1055TE | 1083PB |1006PS). Sustainability sciences carries with it the implication to ‘teach across the disciplines’ (2067PE) in a manner that demonstrates the ‘intimately connected ways of Earth systems that are not fully understood’ (2062PS) and a commitment to teach and learn towards ‘human health and well-being’ through a science and social issues (SSI) approach’ (1054TE).

Representative Statements

1) State of environmental/resource depletion – science education to educate youth on factors contributing to the state of our planet and opportunity for students to become active citizens within their communities to develop initiatives and propose solutions to problems. (1083PB)

2) An interdisciplinary approach to science and SSIs and the skills and attitudes students need to develop to be able to successfully participate in a science classroom where education for citizenship takes place. (1054TE).

3) Critical issues: We are facing increasingly critical issues to do with our planet and the human response to these issues relative to our survival. I would anticipate that science education might respond with an increased focus on understanding how our planet and its systems function, how human activities

impact these systems and how these impacts may be mitigated. (1006PS)

4) Sustainability sciences, like the health sciences and agricultural sciences is a rapidly emerging area of research and teaching that is defined by the problems it addresses rather than the disciplines employed. (2067PE)

5) Sustainability issues should be, and could easily form, the cornerstones for a system where students learn both processes and patterns that will allow them to make informed decisions and to take actions that will lead to addressing the issues of this century. (2009ST)

6) Sustainability science, given the priority that it demands, science education in Canada might well be viewed as being unique and could well be viewed as a distinguishing characteristic both internally and internationally. (2067PE)

New Learning Technologies (Impact Factor = 2.73)

Justification for Emergence

The 'rapid digitization of the classroom and similarly rapid access to masses of information' (1037PB) is a trend with many possible effects among systems of science education at all levels and in both formal and informal learning environments. Included among these effects is a concern that educational environments will continue to lag behind the commercial availability of information technologies and that the science learning experience will become more virtual in the decades ahead (1066TE). A possible symptom of this gap or lag is the demonstrated low completion rates and lack of resiliency among

students involved in independent, online learning such as Massive Open Online Courses (MOOCs) (1098PU). And so, new learning technologies and the manner in which these are synergistic with other networking technologies is ‘a continuing debate in educational circles as to promise and prospects versus limitations’ (1006PS).

The promise of trans-national and international reach of collaborative educational technologies alongside the instantaneous access to key information is seen by some as the new era of educational resources and potentially transformative of science education practices in formal settings. In an almost Kuhnian-type revolution of the role of the textbook in science education, not only is it perceived that ‘textbooks will be re-written almost in real-time’ (2002ST), there is some thoughtful concern over the role and purposes of the ‘science library itself, which may become moribund’ (2062PU). ‘Writing as a means to learning science and representing ideas-to-learn in science have strong historical foundations among educators in science’ (2087PE) and these are likely to be re-presented themselves in entirely new ways through emerging and existing technologies available to the learning experiences of youth and adults alike. Canada is deemed to have ‘strengths in clinical medical education/research, physics and astronomy, communications, and the cognitive sciences’ (2052PD), and these areas will be quick to transform through the availability of hand-held devices and the Bring Your Own Device (BYOD) approaches to education (2009ST).

Representative Statements

1) New technological advances will have a substantial impact on science education. Accessing, communicating and disseminating science information technical advances will be a positive in terms of application of knowledge and understanding basic fundamental and applied principles. The impact this will have on science education for the learner (e.g., taking the student away from the hands on aspects of learning) is difficult to forecast. (1085ME)

2) Science education will be tremendously influenced by the development and introduction of new devices and capabilities in electronics as well as seeking new and creative applications for emerging technologies. (1099ST)

3) Access to simulations of experiments rather than life experiences will make certain topic areas more accessible to teach (like astronomy). (1055TE)

4) Physical groupings of kids (in schools) may limited to laboratory work (e.g., social encounters, experiments in the field, trips, sports etc.). In fact, the more computer simulations are used in science, the more important it will become for science learners to actually see the phenomena in real life – to understand that the simulations are only models of these real phenomena that only capture certain aspects of the reality depending on how the modeller viewed it.

5) It's expensive to develop good, interactive online learning opportunities so funding will be stretched and the scalability of effective practices may be a challenge. (1098PU)

Instrumentation now used to run diagnostic testing has become more technical,

robotic and interfaced with online access. The digital age is expanding and access to information is now global, and allows for instant information sharing and easier collaboration among specialists. (1026 ME).

Relevance of Science Education for Students (Impact Factor = 2.48)

Justification for Emergence

Since the release of the ROSE Study (Relevance of Science Education)¹⁹, and from much of the work done prior to that in the UK and its associated literature, a re-invigorated sense of the students' points of view with respect to their science learning experiences is very much emergent. This study is no different in that continuing account, but participants are emphasizing the term 'student engagement' much more than notions of 'relevance'. Nevertheless, such terms will often be used synonymously unless there is particular reference to the literature having defined the term 'student engagement'.

Participants' views on relevance and engagement include references to 'inspiring curiosity and a sense of purpose in working towards a sustainable future' (1099ST); providing for 'a different entry point into science for both students and teachers such that it is an authentic reflection of what is relevant to their lives daily and also connected to the larger issues and problems of science'

¹⁹ Jenkins, E. W., & Pell, R. G. (2006). *The Relevance of Science Education Project (ROSE) in England: a summary of findings*. Leeds: Centre for Studies in Science and Mathematics Education, University of Leeds. Online at: <http://roseproject.no/network/countries/uk-england/rose-report-eng.pdf>; and Schreiner, C., & Sjöberg, S. (2007). Science Education and Youths' Identity Construction: Two Incompatible Projects?. *The re-emergence of values in science education*, 231. Online at: <http://www.roseproject.no/network/countries/norway/eng/nor-schreiner-values2006.pdf>

(1014PB); having increased ‘science media literacy and enough understanding of the nature of science to assure a natural engagement and to evaluate claims presented to them’ (1037PB); the emergence of the ‘negotiated curriculum as a part of science education that appeals directly to students’ interests without eliminating the role of sound teaching and advising’ (1016PB); ‘socially controversial issues and an increased emphasis on argumentation in science’ (2014TE); addressing both the ‘causes and the consequences of large-scale student disengagement’ (2001TE)’; learning that is explicitly and intentionally interdisciplinary, from classroom out to the community (2009ST), and; the ‘provision in curriculum for more opportunity to cooperate internationally in areas of mutual interest but geographic disparity’ (2095ST).

Representative Statements

- 1) Globalized competition may increase pressure to make science education more appealing to a broader range of students. (2061PU)
- 2) Canada, there is a critical underrepresentation of Aboriginal people going into science-related programs at the post-secondary level. This has impacts for their full participation in scientific communities on an equal footing. ((2042TE)
- 3) For young people, there is less time spent outdoors looking under rocks, wading through streams, and getting dirty. This is partially because of overly-protective parents who do not let their children out of their sight, plus busy schedules filled with hockey practice, music lessons, etc. (2062PU)
- 4) Men and boys do not appear to be receiving the type of education

today that would encourage them to enter science-based areas. However, at the exit level of these programs, particularly at the post-doctoral and junior faculty level, women are leaving in larger numbers than are men. We need to consider seriously whether the science education children receive is appropriate for their needs. (2052PD)

5) A potential consequence of youth disengagement may lead to the rejection of scientific advice, place limitations on scientific research that may have potentially beneficial outcomes for humanity, and reject a body of knowledge that represents one of the great cultural achievements of societies. At a time when science-related issues such as climate change continually surface as political and moral dilemmas facing society, this underscores the significance. (2001TE)

Developing Science-Oriented Skills (Impact Factor = 2.29)

Justification for Emergence

The generalised theme of “skills” is deemed by many participants to be consonant with an increasingly ‘digitised world’ wherein students of science are able to ‘make use of rapid access to large volumes of information online’ (1037PB) through digital technologies. This opens for educators the twin prospects of a need to develop skills in – and to also acknowledge the penetration rate of – emergent technologies. There exists opportunity for students to use the ‘creative application of these technologies’ (1099ST) for the collection of data, the sharing of ideas and analyses of that data, and the platforms of social media as media of communication. The prospects generated by a ‘decreasing need for on-site, physical groupings of students and a radically changed school calendar to

accommodate international collaboration’ (1016PB) and the widespread use of digital modeling and simulation could conspire to create an even greater need for physical contact with the natural environment than what is perceived today. This expanding digital environment does not lend itself to our predictive abilities about its effects, while at the same time systems of education struggle to determine ‘what the skills and competencies will be to be competitive in a global marketplace’ (2001TE)

Tensions are possible as the appropriate pathways to satisfying career trajectories among youth do not easily make connections to an anachronistic system of science education in the formal school system. Some of that tension may exist and be made manifest institutionally, as ‘applied and interdisciplinary programming enters into direct competition with traditional academic and discipline-focused systems of education’ in the sciences and technology (1096PB). The changing role of the traditional ‘confirming laboratory experience’ to one of ‘learning at any time and in any place’ (2080TE) will be driven strongly by readily available Bring Your Own Device (BYOD) approaches that can ‘positively exploit in creative ways the widespread availability of inexpensive, hand-held technologies’ (2095ST). There are views such as the application of these new skills sets in order for science education systems to get ‘plugged in to what is happening around the world with student research’ (1026ME | 2009ST) and to move in the direction of ‘use-inspired basic science’ (2067PE).

Representative Statements

1) Accessing, communicating and disseminating science information and technical advances will be a positive in terms of the application of knowledge and understanding basic fundamental and applied principles. The impact this will have on science education for the learner (i.e., taking the student away from the hands on aspects of learning) is difficult to forecast (1085ME).

2) The way young people learn and communicate is changing – are we considering that adequately, and are we optimizing our approaches to leverage the new skills they are developing? (1091PI)

3) Students will need to understand the nature and practices of science. Digital technologies could really help science move away from the transmission of concepts to getting students actively involved in collecting and analyzing data.

4) Skills and attitudes are part of the civic formation, which I consider to be a trend here, inasmuch as they include not only what has been considered scientific literacy more broadly, but also the ability to search, select, evaluate, interpret, synthesize and relate information that transcends the strictly defined scientific content (1054TE).

5) There will be a trend toward interdisciplinary, workplace-related science courses (e.g., medical science, agricultural science, petroleum science, etc.) (1067PB).

6) A trend away from libraries towards research on the internet and the sharing information on social media. While this provides tremendous access to

global information, the challenge for the student (and the public) is to tell the difference between what is science and what is pseudo-science (2062PS).

Integration of Indigenous Perspectives / Knowledge (Impact Factor = 2.21)

Justification for Emergence

In the period since the Science Council of Canada presented its vision of *Science Education in Canadian Schools* some 30 years ago, there has been a ‘renaissance in the status of indigenous peoples worldwide, including their worldviews and knowledge systems’ (2012PE). Not only is there discourse from the standpoints of ‘indigenous philosophy, ontologies, and culturally responsive pedagogical practices’ (2042TE), there exists a tension from the philosophy and sociology of science education as to the status of indigenous peoples’ knowledge and its appropriate place in the Canadian mosaic of science curriculum. Issues related to concepts of traditional ecological knowledge (TrEK), traditional knowledge (TrK), ways of knowing, and place-based knowledge and wisdom are juxtaposed against a backdrop of underrepresentation in S&T employment profiles and the science and medical research pipelines.

In addition to these viewpoints on the theme of indigenous/Aboriginal perspectives is the degree to which “Euro-centric science” dominates the science curriculum to the exclusion of peoples who struggle exceptionally to see themselves as becoming emancipated from the ‘colonizing influences of the

science curriculum’ (2042TE). Where the debate overlaps into the theological/ontological realm, sharp divisions emerge in instances where a judgement must be made about “what is science?” and “what is not science?” (2061PS) | (2042TE). There are specific references to ‘placed-based approaches to science education’ (1096PB) | (1047PB) and the relationship between prospects for S&T employment options and ‘issues of economic and social justice’ that can be addressed through science curriculum (1054TE).

Representative Statements

1) Science curriculum takes a place-based approach to science learning. Students will develop place-based knowledge about the area in which they live, learning about and building on Aboriginal knowledge and other traditional knowledge of the area. This provides a basis for an intuitive relationship with and respect for the natural world; connections to their ecosystem and community; and a sense of relatedness that encourages lifelong harmony with nature. (1096PB)

2) A major gap is the generally non-existent focus on indigenous ways of knowing, which needs to be an essential component of science education. This emphasis is not specific to provinces that have the highest percentage of indigenous students, but needs to be emphasized in all jurisdictions. Adding this focus is deemed by many aboriginal scholars to be one method of decreasing the achievement gap between aboriginal and non-aboriginal students – partially by providing more opportunities for the former to see themselves and their culture as valued in a science curriculum. (1047PB)

3) There really is no such thing as aboriginal science. There's science, and there's aboriginal knowledge. The two can be fruitfully brought together – and should be – but in no way should science diminish the importance of aboriginal knowledge, nor should aboriginal knowledge undermine science. (2061PU)

4) The inclusion of Indigenous knowledge: (a) alters the power balance between Elders and Ministries of Education (collaboration replaces consultation), (b) requires school jurisdictions to involve Indigenous communities in implementing enhanced science curricula, and (c) moves teachers to engage in culturally responsive science teaching. (2021PE)

Science, Technology, Engineering and Mathematics (STEM) (Impact Factor = 1.92)

Justification for Emergence

The Science, Technology, Engineering and Mathematics (STEM) theme includes references to its existence as a recent re-conceptualization of the core approach to the teaching and learning of science. For some, STEM marks a departure in the foundations of science education away from 'STSE as a planning approach to a distinct realignment from science for citizenship to science for skills development towards employment; especially innovation and leveraging the 21st century economy' (1022TE). It is a consideration that many 'future-oriented employment profiles will require a significant personal background in STEM' (1001PS) and that the direct teaching of engineering and design principles is

‘important to international competitiveness in a globalized economy’ (1067PB) and for the prospects of science and technology as ‘drivers of the innovation’ that leads to a prosperous economy (1098PU).

STEM is also viewed as foundational to the future architecture of science curriculum, teaching, and learning such that it provides a ‘broadly acceptable national vision for science education’ (1067PB|1098PU) and a platform upon which ‘diverse career opportunities across all post-secondary pathways’ can be constructed by students. Interdisciplinary approaches that exist at the interface of STEM and the Arts (as STEAM) are viewed as a point of entry among ‘disenchanted or reluctant generalist teachers of science’ (2087PE|2009ST). There is mention of the ‘science-proficient worker’ (2054TE) that will participate in an inevitably globalized future which will be characterized by increasing dependence upon the influence, the importance of, and the affordances provided by ‘engineering, biotechnology, and other applied science fields’ (2085PE).

Representative Statements

1) According to Human Resources and Skills Development Canada, a great percentage of the jobs of the future require a background in STEM (science, technology, engineering and mathematics). | 1091PI.

2) Globally there is also a need for STEM leaders. That is, leadership skills need to be taught alongside STEM subjects and integrated if possible. | 1001PS.

3) A reduction in teaching process skills such as inquiry and more emphasis on developing engineering skills such as problem articulation and

solving. | 1066TE.

4) Concerns about sustainability, health, energy, and water are examples of significant issues that face today's societies and involve government policies and actions. These issues are interconnected with STEM. | 2001TE.

5) Growth of economic globalisation, growth of the economic impact of S&T, and the consequent growth of the importance of S&T education. 2085PE

Re-conceptualizing the Purposes of Science Education (Impact Factor = 1.29)

Justification for Emergence

For almost a half-century, the “four commonplaces” enunciated by Joseph Schwab in a series of classic papers in *School Review* – being “the subject matter, the teacher, the student, and the learning environment (milieu) – have remained in the centre of discourses about education, and especially the curriculum. Most of us cannot imagine construction of a learning experience in science without appealing to all four of these ‘places’. It has also become rather a commonplace, but not necessarily in the sense that Schwab held the term, to periodically re-conceptualize the curriculum. At various points in time, historically, curriculum dedicates itself pre-eminently to one of these ‘commonplaces’ and at other times looks closely at all four simultaneously. In this study, the commonplaces are readily found. In the letter of invitation sent to you which opened the door to your participation, I declared that “almost three decades have passed since the Science

Council of Canada conducted its *Science Education in Canada* study²⁰ – and we are more than 15 years beyond the Council of Ministers of Education, Canada *Pan-Canadian Science Project*.²¹ It is worthwhile to spend some time reviewing these important episodes to observe the manner in which the ‘four commonplaces’ were re-conceptualized in the science curriculum.

In the present study, participants’ views on re-conceptualization span a wide array of orientations and identification of new (and older) trends, including: indigenous way of knowing (1047PB); social and personal relevance of science and the de-emphasis of academic rationalism (2030TE); participatory and socio-political action (2054TE); sustainability sciences and systems approaches (2062PS); international student collaboration and inquiry (2095ST); inter- and trans-disciplinary approaches emphasizing socio-scientific issues (SSIs) (1054TE) | (1055TE); STEM foci (1016PB); and the ascendancy of other cultures as political/educational/economic superpowers and the decadency of the ‘Anglo-American science curriculum’ (1022TE).

Representative Statements

1) Greater consideration of sustainability issues and perspectives in school science education with a possible impact on the very nature of science education; revisions of science curricula to give consideration to those issues and

²⁰ See Orpwood, Graham W.F. "Toward the renewal of Canadian science education. I. Deliberative inquiry model." *Science Education* 69.4 (1985): 477-489. Available online at: http://www.researchgate.net/publication/227737206_Toward_the_renewal_of_Canadian_science_education_I_Deliberative_inquiry_model/file/d912f50d036a27dec5.pdf and,

Orpwood, G. W., & Souque, J. P. (1985). Toward the renewal of Canadian science education. II. Findings and recommendations. *Science Education*, 69(5), 625-636.

²¹ See/voir: *Common Framework of Science Learning Outcomes K-12* at: <http://publications.cmec.ca/science/framework/>.

perspectives (high impact magnitude). (1055TE)

2) Greater interconnectedness (of school science) as a spin-off of technological advancement may permit many more students per teacher/leader or per outside expert; collaboration with people from around the world, in real time or asynchronously, will increasingly become the norm. New technologies will have shrunk the global village to a global room. (1016PB)

3) The obsolescence of the current educational model is not a stretch. Already educational leaders globally are calling for new forms of schools and school models instead of reforms of existing schools.

4) More teaching of how to use and maintain technology, and less and less about fundamental science; higher-order mathematics will only be required of students headed for advanced study in the sciences. (1051PS)

5) It has been my experience that science curricula tend not to be reconceptualized but rather repackaged. (2001TE)

The Foundations of the Canadian Science Curriculum

Science, Technology, Society and the Environment (STSE)

(Impact Factor 3.61)

Justification for Emergence

This theme comprises a complex system of interrelationships that includes not only the distinctions that exist between science and the development of technologies but how technologies interact with the human environment and the manner in which science is conducted under the shaping influences of technology. While historical episodes of science curriculum change in Canada – certainly since the 1970s – have been informed by the unique (and justifiably Canadian) contributions of STSE to the foundations of curriculum, the data coming forth from this study demonstrates possible new inter-relationships. These novel STSE connections could be considered to result from the ‘deep penetration of new technologies at the level of the individual’ (1016PB). As a consequence, it is not just the abstraction of technology and its relations with science that is informing science education, but science education itself stands to be impacted at depth by technological interventions that will transform (or are already transforming) science learning environments.

At the level of science learning environments, new ‘learning technologies will see an expansion of school models that focus on science and mathematics and engineering principles that serve an “internationalization” and global reach of the future classroom’ (2009ST); science itself ‘is involved in greater degrees of team collaboration among countries to address multi-faceted, regional socio-scientific

issues requiring an extension beyond underlying science concepts’ (2001TE); and that ‘in the future science in actual context is going to become of even greater importance, and the countries whose engineering, biotechnology, and other applied fields are better supported by elementary and secondary science education will become dominant economically’ (2085PE).

STSE as a *literacy* is identified as ‘a mainstream literacy for citizenship and pipeline careers where basic literacies are viewed as just the minimum set of abilities’ (2087PE), and possibly embedded in a ‘technology-rich learning environment including high-grade facilities, multi-media real-time resources, industrial technology access, and as yet unknown communications technologies’ (2009ST).

Representative Statements

1) 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. (2001TE)

2) Environmental issues may steer education content and provide immediate context for science education. (e.g., shale gas development, oil and gas extraction, mining of finite resources, enhanced recovery, etc.) (1085 ME)

3) La question de la culture scientifique et technique est fondamentale. Les citoyens de demain doivent absolument être mieux outillés pour intervenir pour démocratiquement dans les débats de société ou encore pour participer à l’économie du savoir. *The issue of scientific literacy is fundamental.*

Tomorrow's citizens must absolutely be better equipped to intervene democratically in societal debates, or to participate in the knowledge economy.

(2014TE)

4) Only a small proportion of our students will actually become scientists, but everyone will be faced with issues related to science and technology. It is therefore important to focus on scientific literacy through STSE for all of our students. This doesn't necessarily mean that they need a very deep knowledge of all science facts (something that would be impossible anyway), but need to understand some fundamental ideas in science, as well as how science works (the nature of science) in order to evaluate claims made by scientists, governments, corporations, etc. and critically think about science issues represented in the media. (1037PB)

5) Given the structure of the educational system in Canada, particularly in terms of teacher preparation programs, the principal foundation of science education in Canada should be social-scientific literacy. A goal of science education in Canada for the next generation should be ensuring the education of socio-scientific literate citizens who are capable of, and understand the importance of, actively participating in society's most pressing debates. (1054TE)

Science Education for Sustainability and Global Citizenship (Impact Factor = 2.65)

Justification for Emergence

The data coming forward in the study demonstrates quite clearly that perceived external and internal vector forces acting as “drivers” of the future

orientation of science education in Canada can simultaneously be former conceptualizations that have a certain familiarity and new conceptualizations that are being shaped by current conditions and expectations for impending developments. For the purposes of the present study, a “foundation of science education” will encompass what participants view as larger-scale elements that would provide the structure of formal science education and lead to the construction of frameworks that are often the attractors of curriculum development. In a complementary way, a “goal of science education” will tend to answer the question “What are the principal *purposes* of science education?” and therefore identify certain exit-level characteristics, affordances, and competencies that take one beyond the formal education system and into adult life.

With these definitions in mind, the theme of *Science Education for Sustainability and Global Citizenship* emerges from participants’ views as a kind of “meta-level” foundation if one adopts a position that it is not simply one of many different and discrete foundations but is actually the ‘sole purpose of any consideration of science education in the first place’ (1054TE) and directly addresses the question ‘why deliver science education?’ (2067PE). Education for Sustainability (EfS) has a priority status among the OECD countries and their respective education systems and occupies a prominent position in UNESCO member countries and associated institutions (e.g., 2014 brings to a close the UN Decade for Education for Sustainable Development)²² .

²² See <http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/about-us/> .

The manner in which EfS is manifest in the participant data includes a call for developing a ‘new foundational aspect for science education that would not have been present 20 or 30 years ago’ (1083PB)²³. Whether it be ‘critical issues among Earth systems’ (1006PS), ‘natural resources utilization and waste management’ (1096PB | 1008ST), ‘science education for global responsibility and citizenship’ (1054TE | 2036PB), ‘providing the highly-skilled research base demanded for a sustainable society’ (2009ST), ‘indigenous perspectives that consider the 7th generation’ (2021PE), or ‘education for sustainable well-being (2054TE|1055TE)...there are myriad perspectives and arguments presented around this theme.

Representative Statements

- 1) Environmental issues may steer education content and provide context for science education. Eg. Shale gas development, oil gas extraction industry, mining etc. (1085ME)
- 2) Examining the state of environmental/resource depletion – science education to educate youth on factors contributing to the state of our planet and opportunity for students to become active citizens within their communities to develop initiatives and propose solutions to problems. (1083PB)
- 3) Sustainability Issues: The focus on sustainability issues is perhaps the most obvious trend nowadays, and I believe it will continue to be so in the

²³ B. Jickling & A.E. Wals (2008). Globalization and environmental education: Looking beyond sustainable development. *Jour. Curriculum Studies*. Vol. 40 (1). 1-21. Available online at: <http://www.tandfonline.com/doi/abs/10.1080/00220270701684667#.Uysol4Wa85k>

next 15 years, as more problems arise and better solutions are needed, ever more urgently. A great deal is expected from the science and technology fields in terms of innovations that will help us deal with, for instance, an exponentially growing population. Issues related to physical space (urban planning, transportation, and waste management/disposal issues in particular), energy sources (which is especially significant nowadays in Canada), and food production become front and centre in this debate. However, not only innovations are expected, but tying in to this is a change of habits. (1054TE)

4) Critical issues: We are facing increasingly critical issues to do with our planet and the human response to these issues relative to our survival. I would anticipate and expect that science education might respond with an increased focus on understanding how our planet and its systems function, how human activities impact these systems, and how these impacts may be mitigated. (1006PS)

5) Science and engineering instruction within the middle & senior years are needed to help address major world challenges: formulating clean energy supplies, technologies that are also environmentally responsible, the prevention and treatment of diseases old and new, maintaining supplies of food and clean water, and solving the problems of global environmental change. (1008ST)

6) Évidemment, on pourrait toujours s'assurer que l'enseignement des sciences tienne compte des facteurs sociaux et environnementaux afin de favoriser un enseignement des sciences interdisciplinaires. Cette approche pourrait faire en

sorte que l'esprit citoyen se développe à l'école. *Obviously, we could always ensure that science education takes account of social and environmental factors which promote the teaching of interdisciplinary sciences. This approach could ensure that the spirit of citizenship develops at the school.* (2014TE)

7) "Sustainability" and its accompanying "global citizenry" are likewise part of all education, for to silo disciplines is to deny connectedness, when it is understanding connectedness that can be so crucial to an understanding of the dilemma we find ourselves in; students could grasp the differences between an inanimate, sterile planet and one that benefits from the presence of a biosphere, and better still if they could be informed of the "web of life" (from genes to cultures) and made familiar with the wide range of services that a biosphere provides, and upon which we absolutely and completely depend within a constraining dynamic equilibrium. (2067PE)

8) La culture scientifique et l'idée de la formation du caractère pour former les Canadiens en tant que citoyens du monde, afin de préserver et de promouvoir les idéaux multi-culturels canadiens tout en faisant progresser la société en harmonie avec la technologie. *Scientific literacy and the idea of character education to train Canadians as global citizens, and to preserve and promote Canadian multi-cultural ideals while advancing society in harmony with technology.* (1016PB)

9) The importance of students being led to understand how science can be used to address the problems and challenges in our world, and that includes the risks that the use of science must also face. (2085PE)

Interacting Systems and Systems Thinking (Impact Factor = 2.56)

Justification for Emergence

In the Pan-Canadian Science Project (PCSP) of the 1990s, creating connections among the scientific disciplines in ways that would help overcome some of the perennial “silo effects” in science education was taken as an important consideration for curriculum. Indeed, that framework looked upon its *unifying concepts* as ‘a useful way to create linkages among the science disciplines – key ideas that integrate across the disciplines’ in ways that characterize both the theoretical structures of major science disciplines and assist the teaching and learning process²⁴. Some 20 years later, the PCSP’s four unifying concepts of constancy and change, energy systems, similarity and diversity, and systems interactions are being granted an opportunity for continued discussion in the data from this study through the *complexity sciences* and *systems thinking*. For instance, the language of systems and a systems thinking orientation is evident that the cross-cutting relationships that are identified in the recently-released *Next Generation Science Standards* (NGSS) in the United States.²⁵

The application of systems thinking in the study data comes in a diversity of forms, such as: ‘science education becoming more of a study of systems dynamics and how these interact’ (2062PS); the ‘involvement of elders as the traditional land users who have retained, and can share, their worldview where

²⁴ See: *Common Framework of Science Learning Outcomes K-12* at: <http://publications.cmeec.ca/science/framework/p.15>

²⁵ For details on the NGSS, see: <http://www.nextgenscience.org/next-generation-science-standards> and for the Cross-Cutting Concepts, see: <http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf>.

everything is considered as connected’ (2042TE); science education, as with all education generally, should be injected with the fundamental processes of systems thinking’ (2067PE); ‘science education has an analog in the “forest school” where biophilia is cultivated through a deep appreciation of ecosystems services and ecosystems dynamics’ (2054TE); and ‘exploring the interconnectedness of things at local and global levels of reach, examining critical issues from multi-perspectives’ (2036PB).

Representative Statements

1) The atmosphere, hydrosphere, cryosphere, biosphere, and lithosphere of the planet are all intimately connected in ways that are not fully understood. And all are changing both through natural processes and through human intervention. Humanity is part of that system and can no longer consider itself as separate. (2062PS)

2) With each step in systems thinking, complexity increases, and interactions become non-linear with emerging outcomes that can be surprising and difficult to predict. Nonetheless, the process of systems thinking is extremely educational creating understanding and a real-time view of how the world works, along with the possibility of recognizing that system function is often subject to the phenomenon of feedback (both positive and negative). We live in a world of systems, and once this is understood the consequences of intervention can be more readily recognized and where leverage points most likely exist. Not only is systems-thinking an extremely useful practice in itself, but it is essential to the

main message that permeates any prevailing response to the current exercise.
(2067PD)

3) We are facing increasingly critical issues to do with our planet, and the human response to these issues relative to our survival. I would anticipate that science education might respond with an increased focus on understanding how our planet and its systems function, how human activities impact these systems, and how these impacts may be mitigated. (1006PS).

Scientific Oriented Skills (Impact Factor = 1.94)

Justification for Emergence

Just as STSE and the Nature of Science have solidified their presence internationally among the foundations of science education for some decades now, it may be equally certain that these archetypal, traditional foundation areas in science education could well undergo some new demand for responsiveness to new conditions. Scientific skills, attributes, habits of mind, and similar language and grammar of science curriculum are now interfacing with perceptions of what constitutes 21st century learning. For this study, it is a more sharply defined and discretely defined skills sets approach to learning.

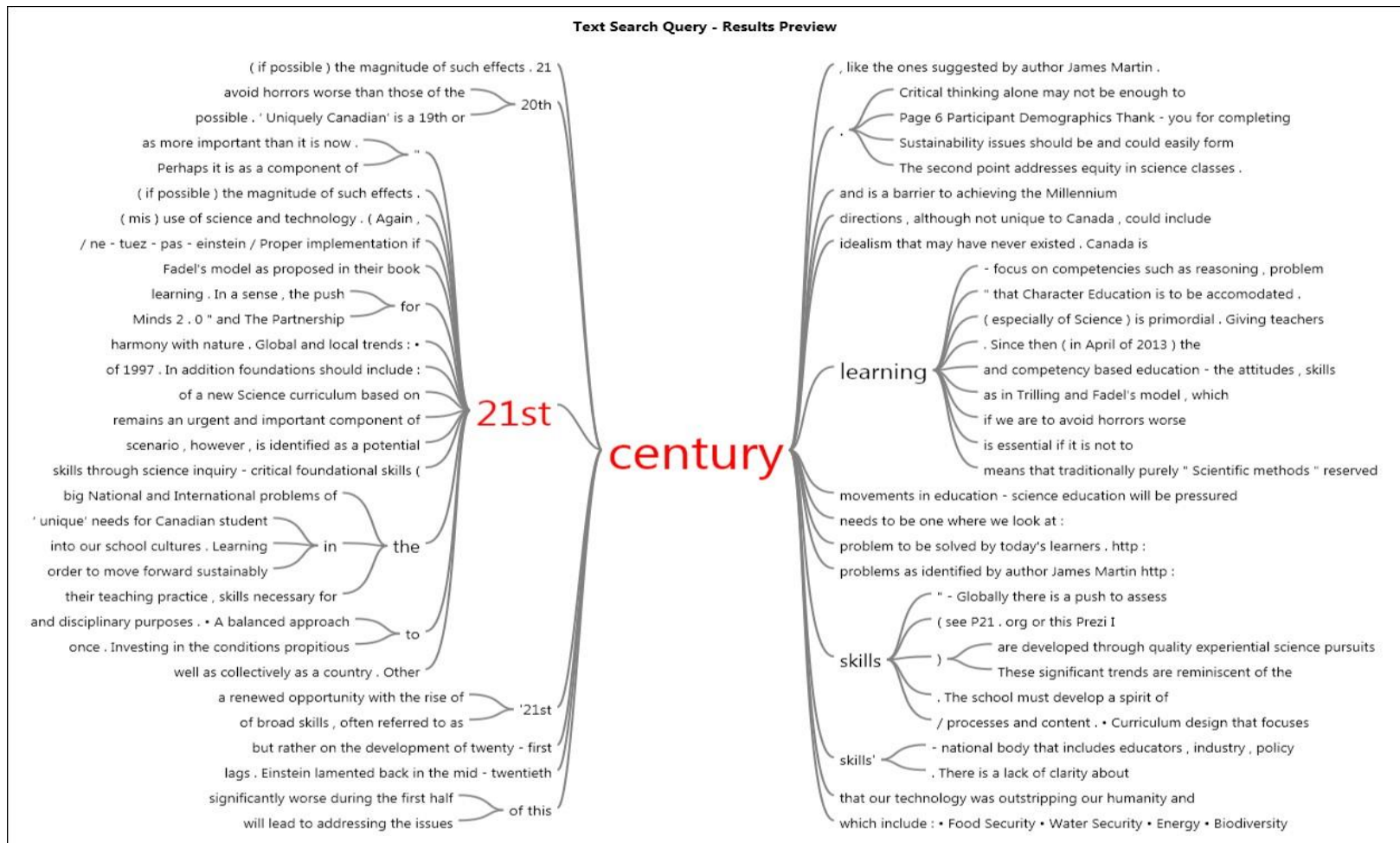
The discourse emerging in this study includes diverse reasons for a continued emphasis on skills, but often with poorly-defined sets of skills or a multitude of perspectives of just what those skills are attributed to. It will be useful for the reader to go back to the Global Trends summary in the section entitled Developing Science-Oriented Skills (page 209) and become re-acquainted

with what the expert council assembled in this study considered to be trends in skills development. In the responses, linkages were made between ‘scientific skill development and the role of inquiry opportunities for students to increase their sophistication with respect to skills’ (1098PU); the ‘5 C’s of communication, collaboration, critical thinking, creativity, and citizenship as these contribute to a skilled proto-researcher’ (2009ST); science literate graduates with a subset adequately prepared for advanced study in the sciences (1098PU); lessening the mathematical skills required in science among those who are not ‘science inclined’ (1051PS), and; raising engineering design to a level that equates to the traditional role of inquiry in science classrooms (1008ST). In order to provide a view of the many contexts that are subsumed by the notion of scientific-oriented skills, the word trees on the succeeding pages provide an indication of how the word “skills” is used in the responses of the panel. Seventeen members of the panel make specific but ill-defined (in many cases) references to skills. It must be noted carefully too how in instances where skills is used, 38 members of the panel make 87 direct references to ‘skills’. Within this number, eleven of the participants make direct references to “21st century skills” or “21st century learning”. Here, there is the possibility for a blurring of boundaries among traditional notions of skills for scientific inquiry, a “new” set of scientific skills deemed appropriate to solve future problems, and a generic suite of skills for learning that are also tagged with the phrase ‘21st century’. This will warrant some further reflections from the data as it is analysed in Chapter 6.

Figure 18: Word frequency analysis tree – use of the term “skills”.



Figure 19: Word frequency analysis tree – use of the term “21st Century”.



Representative Statements

1) Maintenant, les élèves peuvent accéder à l'information à partir de la maison. L'école n'est plus un lieu où le savoir est détenu. L'école doit être un lieu où on partage nos informations et on résout nos problèmes ensemble.

Programmes devraient être moins axés sur le contenu d'apprentissage, mais plutôt sur le développement des compétences du XXI^e siècle. *Now, students can access information from home. The school is no longer a place where knowledge is held and detained. The school should be a link where we share our information and we solve our problems together. Curricula should be less focused on content learning, but rather on the development of twenty-first century skills.* (2014TE)

2) There will always be a requirement for basic knowledge and skills in sciences such as mathematics, chemistry, biology, and physics. (2052PD)

3) Learning science in a manner that reflects the construction of new knowledge by the scientific community – inquiry / empirically testing ideas, reasoning about the evidence observed and measured, development of models using evidence, checking for internal consistency and coherence, discourse and argumentation focused on data and the conclusions drawn from data / evidence. (2054TE)

4) Use science and technology to acquire new knowledge and solve problems; critically address science-related issues; practice teamwork; gain knowledge of the wide variety of careers related to science and technology; develop a proficiency in science that will create opportunities for them to pursue progressively higher levels of studies. (2009ST)

5) Poser des questions et la définition des problèmes, l'élaboration et l'utilisation de modèles, la planification et la conduite des enquêtes ; l'analyse et l'interprétation des données ; l'aide d'outils mathématiques, la construction d'explications ; s'engager dans l'argument de la preuve, l'obtention, l'évaluation et la communication des informations. *Asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematical tools; constructing explanations; engaging in argument from evidence; obtaining, evaluating and communicating information.* (1037PB).

The Nature of Science (Impact Factor = 1.35)

Justification for Emergence

An increased emphasis on the *Nature of Science* (NOS) in science curriculum has been evident for at least a generation but from time to time it re-emerges as a considered foundation area with a certain freshness. That appearance of 'freshness' may be due to perceptions of the contested nature of the NOS among the scientific and science education communities. In particular, it was generally accepted that there was widespread dissensus in identifying what the priority emphases should be regarding the NOS. Eventually, one of the only Delphi studies (in addition to the current one) that solicited expert panel opinion on what students should know about the nature of science²⁶ was completed in

²⁶ Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40(7), 692-720. Online at: <https://cset.stanford.edu/sites/default/files/files/documents/publications/Osborne-%2522Ideas-about-Science%2522.pdf>.

2001 and shed some light on the issue. The Osborne *et al.* (2003) study may have provided the science education community with the beginnings of consensus-building on what constitutes foundational NOS – at least in U.K. schools.

About 30 years ago, an influential heuristic was developed by the Canadian science education R&D specialist Douglas Roberts – *curriculum emphases*.²⁷ Much of what we consider as important to student appreciation and accommodation of conceptions related to the nature of science and its practical application in school science has not changed very much in three decades. The participants in this study point to many traditional aspects of NOS, including: respecting evidential arguments and the provisional nature of scientific knowledge (1096PB); the diversity of scientific inquiry approaches and a discrediting of the iconic ‘scientific method’ (1014PB); how ‘science is done, communicated to its community and a wider audience’ (1013ST); over emphasis on discrete facts and algorithmic manipulation at the expense of opportunities to do science and develop a lasting, working knowledge of the processes of science and evidence-based decisions’ (2061PU | 2088PE).

Representative Statements

1) Learning science in a manner that reflects the construction of new knowledge by the scientific community – inquiry / empirically testing ideas,

²⁷ Roberts, D. A. (1982). Developing the concept of “curriculum emphases” in science education. *Science Education*, 66(2), 243-260. Online at: <http://www.kcvs.ca/martin/EdCI/literature/literacy/roberts.pdf>; and Roberts, D. A. (1988). What counts as science education?. *Development and dilemmas in science education*, 27-54. Online at: <http://files.eric.ed.gov/fulltext/ED309081.pdf#page=42>.

reasoning about the evidence observed and measured, development of models using evidence, checking for internal consistency and coherence, discourse and argumentation focused on data and the conclusions drawn from data/evidence.

(2054TE)

2) Understanding of scientific research as a process, based on drawing conclusions from evidence, in a community structure; examine the limits of science, to understand that science is a cultural product and that people can come to different conclusions based on the same evidence, given different background assumptions, values, cultural norms. (2075PD)

3) Learning science in a manner that reflects the construction of new knowledge by the scientific community – inquiry / empirically testing ideas, reasoning about the evidence observed and measured, development of models using evidence, checking for internal consistency and coherence, discourse and argumentation focused on data and the conclusions drawn from data / evidence. (2054TE).

The Goals of Canadian Science Education

Scientific Literacy, Personal Development and Life-Long Learning

(Impact Factor = 2.65)

Justification for Emergence

In 1958, educational psychologists and other interested parties convened a seminal conference at Woods Hole, Massachusetts. Paul Hurd, then of Stanford University wrote a brief article in *Educational Leadership* entitled *Science*

*Literacy: Its Meaning for American Schools*²⁸. In that article, Hurd attempted to argue persuasively for a new kind of literacy, articulating that:

“Attempts to define human values, to understand the social, economic and political problems of our times, or to validate educational objectives without a consideration of modern science, are unrealistic. More than a casual acquaintance with scientific forces and phenomena is essential for effective citizenship today. Science instruction can no longer be regarded as an intellectual luxury for the select few. If education is regarded as a sharing of the experiences of the culture, then science must have a significant place in the modern curriculum from the first through the twelfth grade.” (p. 13).

This study’s participants have identified personal development (1085ME), character development (1016PB), and life-long learning (2052PD | 1096PB) as contributing to (perhaps) a 21st-century form of the enduring concept of *scientific literacy*. It is a broad and contested area of interest that has been captured in a manner which continues to call for its inclusion more than 50 years after its initial appearance in public discourse. Aspects of scientific literacy from among participants include: a learning culture around the sciences (2009ST), fostering a sense of personal awe and wonder (1022TE | 2088PE), a life-long continuous education in the sciences (2052PD), the ability to bring forward the perspectives of science to decisions and actions (1096PB), the informing of engaged citizenship (1022TE | 1014 PB), and to cultivate the joy of learning through

²⁸ Hurd, P.D. (1958). Science literacy: Its meaning for American schools. *Educational Leadership*, 16(1), 13-16. Online at: www.ascd.org/ASCD/pdf/journals/ed_lead/el_195810_hurd.pdf.

science (2054TE). How one *defines* scientific literacy remains as important as any *argument* for its inclusion as a goal.

Representative Statements

1) We need to accept that scientific education does not cease when a student graduates. The need for more and better continuing education programs in the sciences should be a goal for all higher educational institutions. There has been a failure to recognize that the acquisition of scientific knowledge needs to be life-long. (2052PD)

2) School science should help students form or enhance the self-identities they bring to the classroom and engage successfully in school science without setting aside or devaluing their cultural self-identities. (2021PE).

3) Lifelong interest in science and the attitudes that will make them scientifically literate citizens who bring a scientific perspective appropriate to social, moral, and ethical decisions and actions in their own lives and culture. (1096PB).

4) A goal of science education could not only be to prepare science-bound students for their post-secondary careers, but also, and perhaps more important, to arm non-science inclined students with a working knowledge of the processes of science, the importance of evidence-based decision making, and the ability to discern the difference between opinion resting on ideology and opinion resting on evidence. (2061PS).

Science Literacy for a Sustainable Society (Impact Factor = 2.16)

Justification for Emergence

Participants generally view *scientific literacy* as both a foundation area in science education and one that contributes to the goals of science education. The former is problematized and made contestable by issues surrounding what makes a ‘literacy’ meaningful in science, while the latter is more often narrowly defined as exit-level competencies, desired ends, or defined by specific goal-oriented statements.

The discourse in this study with respect to literacy in science takes on variety of interests and perspectives, including: science for ecological literacy (2054TE), science for engagement in environmental responsibility (1022TE), science for meaningful personal contributions to society through citizenship and action (1055TE | 1091PI), science towards the goals of sustainable development and global citizenship (1083PB | 2026PB), science education for functioning in the environmental, economic, political, cultural, and historical systems within which they are embedded (1054TE), and science education as contributing to the improvement of levels of health and well-being in earth systems (2067PE).

There are references to equipping citizens with the knowledge and understandings requisite towards an environmentally responsible and aware society (1022TE); to identify the pressing questions of the day and be well-positioned to assess options (1005PS); the ability to collect, judge and evaluate evidence from a community-based understanding of science (2075PD); and the possible impediments to achieving literacy goals in a culture of globalised

standards assessments (e.g., PISA) that has not yet achieved satisfactory ability to assess for these attributes systematically (2001TE).

Representative Statements

1) I think an educated citizenry needs to be able to understand the impact of policies and practices and be able to have a voice in shaping these. To do this they do need a level of scientific literacy which involves some balance of specific knowledge and well as the ability to ‘get smarter’. (1066TE)

2) La culture scientifique, relié à l’idée de la formation du caractère comme objectifs de former les Canadiens en tant que citoyens du monde, afin de préserver et de promouvoir les idéaux multi-culturels canadiens tout en faisant progresser la société en harmonie avec la technologie de manière durable.

Scientific literacy, connected to the idea of character education as goals to form Canadians as world citizens in order to preserve and promote Canadian multi-cultural ideals while advancing society in harmony with technology in a sustainable way. (1016PB)

3) We live in a world of systems, and once this is understood the consequences of intervention can be more readily recognized and where leverage points most likely exist for science education. Not only is systems-thinking an extremely useful practice in itself, and educative, but it is essential to the main message that permeates any prevailing response to the current exercise. (2067PD)

4) This is important because citizenship education is one of the overarching goals of school education, and science education has the responsibility to contribute to that goal. Considering that natural science issues are

central to a modern society like Canada, a science-understanding citizenry is as relevant as are ethically responsible scientists. (1055TE)

5) The focus should continue to be on the goal of scientific literacy and a minimum level of literacy to ensure engaged, informed citizenship. The importance of this to Canadian society is self-evident (1014PB).

Science for Career-Building and Economic Competitiveness (Impact Factor = 1.19)

Justification for Emergence

Participants have brought forward a set of views that frame the goals of science education as including economic advancement for the nation and security of employability among its citizens. Evidence was brought forward to indicate the perception, if not the reality, of certain countries placing much greater emphasis and priority on science and mathematics education than others (1083ME | 1014PB). Consideration emerges as to nurturing Canada's ability to compete in the global marketplace (1026ME) and thereby afford the country an advantageous position socio-economically in the world community (2080TE).

In a general way, consideration about innovation (1014PB) and ensuring that Canadian science education opens up avenues and prospects for science and technology-related career options (1001PS | 1098PU) is considered in the light of what a STEM-focused framework for science education could achieve. These STEM-oriented pathways are thought to require the collective engagement of the skilled trades, colleges and the universities in a diversity of ways appropriate to their respective strengths to cultivate real career alternatives and opportunities

(1091PI | 2080TE). In addition to these considerations about skills development, skills gaps, and career aspirations, there is a reminder that under-representation in science-related career and employment among Aboriginal and immigrant populations constitutes an area of concern – not only for scholars of science education (2021PE) but for those who advocate for narrowing this gap through novel curriculum emphases (1047PB).

Representative Statements

1) Globally, other jurisdictions place a much higher priority on math and science education than is done here in this country. This has the potential of leaving Canada in a much less competitive position. Poor results from mathematics in recent global test findings/results are consistent with this. (1083ME).

2) There is less focus on basic science today than on gaining the “experience” in order to find a suitable job. That said, the demand for science education that helps to meet that outcome is becoming more important. Fewer jobs will be found in academia than in industry. Research positions in government are being cut. I think we will see students seeking the hands on skills, and technical skills, needed to succeed in jobs rather than focussing efforts on pushing science further than the ones before them did. (1092PS)

3) Science is not being viewed as a career choice or engaging area of study by enough Canadian students. By creating a more inclusive view of science, students will be more likely to identify with and engage with science. (1014PB)

- 4) Science education is expensive and requires a long term vision of where a province or country wants to go. This is presently lacking in Canada. Our focus is very much on short term development of the resource-based economy to provide jobs. (1005PS)
- 5) Currently we provide students with many opportunities to see themselves as not being able to do science – we continually reinforce this by categorizing sciences as either being hard or soft; given an excuse, many students thus look at their options and can avoid the mathematical and physics experiences which would likely benefit them. (2009ST)
- 6) Science education across Canada and internationally is influenced strongly by the ‘academic rationalist’ mentality and so it ‘sieves’ out students to service a model that is largely about economics. (2030TE)
- 7) Rather than have the study of university science be the main goal of secondary school science, I believe that a much broader range of goals is required for the majority of students. (2085PE).

The Canadian Context

The following section of this chapter is somewhat of a departure from the previous sections as it outlines more general commentary from Questions #3 and #4 from the Round 1 questionnaire. These questions were as follows:

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.*

What follows are general summaries of what was generated from the latter two seed questions of Round 1. The rating scales developed for Rounds 2 and 3 had their basis in these large-scale themes across two major sets of ideas: (1) Opportunities and Barriers for the Development of a New National Vision for Science Education in Canada, and; (2) a Canadian Approach to Science Education. In a succeeding chapter, the expert panel responses will address the more finely-divided aspects of these two themes and how they are connected explicitly to the research questions.

Opportunities and Barriers to a National Vision for Science Education in Canada

(Overall Impact Factor = 5.67; Opportunities = 2.68; Barriers = 2.86 N=51)

Justification for Emergence

Participants have identified an array of contexts that are considered to be of influence in defining the future landscape of Canadian science curriculum, including: the nature of Canadian communities and cultural diversity; First Nations / Métis / Inuit (FNMI) perspectives; the possibility of national standards

(e.g., STEM); the legacy of the Pan-Canadian Science Project of the 1990s, and; the role of the Council of Ministers of Education Canada (the CMEC)²⁹. 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 context of any discussion 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 (2095ST | 2002ST). Canada is also observed to be defined, in part, by its vast geography and circumpolar position and these defining characteristics could affect the kind of science education envisioned (2052PD | 2014TE). FNMI perspectives on the planet have emerged as important to consider in any discussion about the future of science education, from the standpoint of ensuring cultural voices in curriculum are heard and ensuring a culturally respectful and responsive curriculum (2067PE | 1026ME).

Participants provided recollections and retrospectives on the Pan-Canadian Science Project (PCSP). Initiated in 1995, this process culminated with the release in 1997 of the *Common Framework for Science Learning Outcomes K-12*, the first (and only) national curriculum framework that was developed under the aegis of the Pan-Canadian Protocol on Collaboration on School Curriculum³⁰. A few years prior to this, the foundations for this national collaboration were laid in September 1993, when the CMEC endorsed the Victoria Declaration, which

²⁹ Pour plus de renseignements sur le Conseil des ministres de l'Éducation, Canada voir: <http://www.cmec.ca/fr/>. For more information on the Council of Ministers of Education, Canada see: <http://www.cmec.ca/>.

³⁰ See/voir: *Common Framework of Science Learning Outcomes K-12* at: <http://publications.cmec.ca/science/framework/>.

outlined a plan for future directions in Canadian education. The Declaration outlined the following beliefs held in common by the Ministers:

“We believe that education is a lifelong learning process. We also believe that the future of our society depends on informed and educated citizens who, while fulfilling their own goals of personal and professional development, contribute to the social, economic, and cultural development of their community and of the country as a whole. Beyond our borders, Canadian education should reflect the priorities of Canadians while contributing to strengthening Canada's place internationally.”

The future role and authority of the CMEC for the purposes of initiating science curriculum change generates tensions among participants. Some view the CMEC as a national body holding real potential for the development of a new national vision for science education (1083ME |1001PS); others seek to re-invest in the CMEC through new abilities to respond appropriately and at levels within the system which address the needs of the education system more regionally/locally (2085PE); while others are less sanguine about the ability of the CMEC to transcend political interests, have its role understood more widely in Canada, or to recognize that science education is a priority area (2060PS | 2001TE).

Representative Statements

1) Although I am supportive that 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. 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 the political will within the jurisdictions that science education is important enough for discussion. Presently the key activities that the Ministers of Education have agreed to act upon are not explicitly related to science education. (2001TE)

2) The voices of the indigenous peoples of Canada are now being heard. Across this country, changes are occurring and the movement will gather momentum. There is a great opportunity to begin the indigenization of the science curriculum. (1026ME)

3) Launch a Canadian taskforce consisting of provincial representatives from the Canadian science teachers' associations, the science and technology industry as well as [post-secondary] teachers to work together to develop a new national vision for science education. (2088PE)

4) The principal goal of science education in Canada for the next generation should be through the idea of integrating mathematics, technology and engineering into a set of science standards. (1008ST)

5) The provinces all participate on the Council of Ministers of Education, Canada (CMEC). The CMEC brings together the provinces to look at issues from a pan-Canadian perspective, and can bring together a new national vision for science education in Canada. (1083ME)

6) The current [provincial] system favours innovation in science education because visionary ideas within one province can be implemented, and

its success can guide other provinces towards that innovation. The innovators are not held back by the inertia of the status quo. The Pan-Canadian Science Framework is a case in point. The compromises and concessions made by reaching a federal consensus diluted some of the innovations of several provinces. (2021PE)

7) A major gap is the generally non-existent focus on indigenous ways of knowing, which need to be an essential component of science education. This emphasis is not specific only to those provinces that have the highest percentages of indigenous students, but needs to be emphasized in all jurisdictions. (1047PB)

8) Cooperation between provincial departments of education should lead to better developed and supported programming at reduced cost in all provinces regardless of the local economic climate. Cooperation on development of educational resources could be facilitated by alignment of programs. (2095ST)

9) I believe that the constitutional provisions for the provincial control of education is a good one. I have never been of the opinion that the federal government could do a better job of operating education than the provinces and territories. That said, however, I believe that the provisions for national dialogue and collaboration in education in Canada are a major failure of our system. The Council of Ministers of Education, Canada (CMEC) provides for these activities at the ministerial and deputy ministerial level but otherwise they offer little for ministerial officials in specific areas (such as science education)

and nothing at all for science educators at the school board and classroom level.
(2085PE)

10) Approximately every 15 years, we see the provinces getting together for a more united and focussed look at science education. Papers are produced, curriculum frameworks are developed, national testing/assessment is agreed upon, and then each province goes its separate way. Pan-Canadian initiatives are less highly regarded because they provide only a basic framework.
(2080TE).

A Canadian Approach to Science Education? (Impact Factor = 2.75, N = 28)

Justification for Emergence

Participants, when assessing the definition of what is meant by “a Canadian approach” to science education, have developed a multitude and a diversity of meanings for the terminology. It is a phrase that will not likely become axiomatic (self-evident). So much so that these ‘approaches’ span the range of (in no particular order of importance): the integration of ‘indigenous ways of knowing from a sense of place’ (1047PB); Canada and partner countries acting as ‘international hubs for schools of science and technology’ (2009ST); ‘socio-scientific issues based (STSE) approaches to curriculum’ (2087PE); Canada as representative of an ‘uniquely stable, multicultural society embedded within the international community’ (2021PE); inclusive of ‘approaches that reflect local / regional / jurisdictional / national contexts’ (2001TE); areas of ‘Canadian specialisation among science disciplines’ (2052PD); a physical

‘landscape diversity that will affect the priorities of science education’ (2052PE); the universality of science versus the threat of nationalistic impulses for its application’ (2062PU), and; what makes science different elsewhere is the delivery, not the core message’ (2002ST).

Representative Statements

1) Canada has areas that are relatively unique to this country, including the arctic, oceans and fisheries, environmental and climate studies, etc. (2052PD)

2) Specific application [of science education] to Canada is in its utility in educating our learners to do their part to solve the big national and international problems of the 21st century. (1016PB)

3) The inclusion of indigenous knowledge (a) alters the power balance between Elders and Ministries of Education (collaboration replaces consultation), (b) requires school jurisdictions to involve indigenous communities in implementing enhanced science curricula, and (c) moves teachers to engage in culturally responsive science teaching in various degrees. (2021PE)

4) I don't think it is necessary or even critical to have a distinctly Canadian approach to science education as long as the curriculum embodies the values of cultural inclusion, where possible, and emphasizes the values of gender equality. (2088PE)

5) Uniquely Canadian may not be the best way to describe it - I would rather see a uniquely global approach where sustainability issues could

easily form the cornerstones for a system that will allow them to make informed decisions and to take actions. Canadian students are now able to work with international peers on their learning and perhaps should be able to gain credits for their efforts. (2009ST)

6) Nous devons respecter les différences culturelles et locales.

L'enseignement des sciences tient compte des facteurs sociaux et environnementaux afin de promouvoir l'enseignement des sciences interdisciplinaires. Toutes les affaires de théologie de l'État doivent absolument être exclus des approches possibles pour l'enseignement des sciences. *We must respect cultural and local differences. Science education takes account of social and environmental factors to promote the teaching of interdisciplinary sciences . All matters of state theology must absolutely be excluded from the possible approaches to science education.* (2014TE)

7) In today's globalised world, it is a good question whether there should be, or even could be, a uniquely Canadian approach to science education. (2001TE)

8) If sustainability science were to be given the priority that it demands, science education in Canada might well be viewed as being unique and could well be viewed as a distinguishing characteristic both internally and internationally. (2067PD)

9) Each country is unique. Respecting local differences is important. But students should learn about national differences, and their origins and impacts. (2075PD)

10) There will always be a uniquely Canadian approach to science education because of our provincial structure, our history, our geography, and for all the other factors that make us uniquely Canadian. However, as globalisation in all areas grows so our thinking and practices in science education will draw from those of others in the international community. The biggest challenge is to develop "a Canadian approach" as distinct from an "Alberta approach", a "Quebec approach," an "Ontario approach", and so on. There are already good ideas in all provinces that are not shared because of the "silo" character of provincial education. (2085PE)

“Canadian society is experiencing rapid and fundamental economic, social, and cultural changes that affect the way we live. Canadians are also becoming aware of an increasing global interdependence and the need for a sustainable environment, economy, and society. The emergence of a highly competitive and integrated international economy, rapid technological innovation, and a growing knowledge base will continue to have a profound impact on our lives. Advancements in science and technology play an increasingly significant role in everyday life. Science education, therefore, will be a key element in developing new literacies and in building a strong future for Canada's young people.”

(from the Pan-Canadian Framework vision statement)

and.....

“Tomorrow's citizens and decision-makers are in school today - are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future.” (Science Council of Canada, SCC,1984c, p. 9)

Assessing the Themes in Rounds 2 and 3 of the Delphi

The Round 2 questionnaire³¹ provided both cohorts of the expert panel an opportunity to engage in rating scales across each of the 47 themes which had been generated by their responses to the initial round and its four seed questions. Prior to this point, all had received a 37-page summary outlining the broad spectrum of themes and representative anonymous comments obtained from the coding of the Round 1 responses. Figure 18 provides an example of how the summary information looked:

³¹ The complete instrument is available in Appendix 'M'

Figure 18: Sample theme presentation and its justification as provided in Round 2.

Science Education in Canada – A Delphi Study

QUESTION 3 | OPPORTUNITIES AND BARRIERS FOR THE DEVELOPMENT OF A NEW NATIONAL VISION FOR SCIENCE EDUCATION IN CANADA

Theme – The Canadian Context

Justification for Emergence

Participants have identified an array of contexts that are considered to be of influence in defining the future landscape of Canadian science curriculum, including: the nature of Canadian communities and cultural diversity; First Nations / Métis / Inuit (FNMI) perspectives; the possibility of national standards (e.g., STEM); the legacy of the Pan-Canadian Science Project of the 1990s, and; the role of the Council of Ministers of Education Canada (the CMEC)¹⁷. 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 context of any discussion 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 (2095ST | 2002ST). Canada is also observed to be defined, in part, by its vast geography and circumpolar position and these defining characteristics could affect the kind of science education envisioned (2052PD | 2014TE). FNMI perspectives on the planet have emerged as important to consider in any discussion about the future of science education, from

Figure 18 continued...

the CMEC through new abilities to respond appropriately and at levels within the system which address the needs of the education system more regionally/locally (2085PE); while others are less sanguine about the ability of the CMEC to transcend political interests, have its role understood more widely in Canada, or to recognize that science education is a priority area (2060PS | 2001TE).

Representative Statements

1) Although I am supportive that 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. 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 the political will within the jurisdictions that science education is important enough for discussion. Presently the key activities that the Ministers of Education have agreed to act upon are not explicitly related to science education. (2001TE)

2) The voices of the indigenous peoples of Canada are now being heard. Across this country, changes are occurring and the movement will gather momentum. There is a great opportunity to begin the indigenization of the science curriculum. (1026ME)

3) Launch a Canadian taskforce consisting of provincial representatives from the Canadian science teachers' associations, the science and technology industry as well as [post-secondary] teachers to work together to develop a new national vision for science education. (2088PE)

4) The principal goal of science education in Canada for the next generation should be through the idea of integrating mathematics, technology and engineering into a set of science standards. (1008ST)

5) The provinces all participate on the Council of Ministers of Education, Canada (CMEC). The CMEC brings together the provinces to look at issues from a pan-Canadian

Similar to the methods of analysis employed by Collins *et al.* (2001) and Osborne *et al.* (2003), each of the themes rated by the expert panel generated descriptive statistical summaries of which included means, medians, modes, and standard deviations. These data were collated across the two cohorts together with both required and optional commentary provided by the participants. It is important to point out that the comments in Rounds 2 and 3 served the purposes of individual argument for why a particular theme received the rating it did and an opportunity to provide clarifications about how the theme was interpreted by the respondent. Tables 7 (Round 2 data) and 8 (Round 3 data) below provide a comprehensive summary of the theme ratings for Rounds 2 and 3. In Chapter 6, I will examine the data with specific reference to the research questions.

Table 6: Theme Ratings for COHORTS 1 and 2 in Round 2.³²

ROUND 2										
THEMES – GLOBAL TRENDS & SCIENCE EDUCATION										
(Perception of Actual Influence)										
	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science, Technology, Engineering & Mathematics (STEM)	3.91	4	4	0.73	69.57%	3.90	4	4	0.72	70.00%
Integration of Indigenous Perspectives / Knowledge	3.48	4	4	0.85	52.17%	2.95	3	3	1.02	23.81%
Developing Skills for the 21st Century	4.35	4	4	0.71	95.65%	4.25	5	5	0.97	75.00%
Science and Education for Sustainability	4.04	4	4	0.64	82.61%	3.81	4	3	0.93	57.14%
National/International Student Assessments (e.g., PISA, TIMMS)	3.59	4	4	0.73	63.64%	3.63	4	3	0.96	52.63%
New Learning Technologies	4.09	4	4	0.73	86.96%	3.81	4	4	0.81	66.67%
Relevance of Science Education to Students	3.91	4	4	0.79	73.91%	3.67	4	3	1.06	52.38%
National / International Standards	3.35	3	3	0.83	39.13%	3.70	4	4	1.13	65.00%
Science Education for Economic Competitiveness	3.57	3	3	0.9	47.83%	3.55	4	4	1.15	55.00%
Reconceptualising the Purposes of Science Education	3.52	3	3	0.95	47.83%	3.29	3	3	1.23	33.33%
Globalization of the International Community	3.35	3	3	0.83	39.13%	3.60	4	4	0.88	55.00%

³² **Notes to Tables:** A positive CONSENSUS (acceptance position) is defined by one or more of the following occurring simultaneously: Mean \geq 3.80, S.D. \leq 0.75, Mode = 5, Consensus Level \geq 70.00%; a negative CONSENSUS (rejection position) is defined by one or more of the following occurring simultaneously: Mean \leq 3.10, S.D. \leq 0.75, Mode \leq 3, Consensus Level \leq 30.00%; a DISSENSUS (polar, bimodal positions) are usually characterized by Mean \approx 3.00, S.D. \geq 1.15. In the instance of dissensus, median and mode values lose significance in the descriptive statistics.

ROUND 2										
THEMES – GLOBAL TRENDS & SCIENCE EDUCATION										
(Desired Influence by Expert Panel)										
	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science, Technology, Engineering & Mathematics (STEM)	3.91	4	4	0.90	65.22%	3.81	4	4	0.98	61.90%
Integration of Indigenous Perspectives / Knowledge	3.61	4	4	0.84	60.87%	3.38	3	4	1.07	47.62%
Developing Skills for the 21st Century	4.26	4	4	0.69	95.65%	4.29	4	5	0.78	80.95%
Science and Education for Sustainability	4.26	5	5	0.92	78.26%	4.48	5	5	0.68	90.48%
National/International Student Assessments (e.g., PISA, TIMMS)	2.91	3	3	0.75	22.73%	2.95	3	4	1.13	36.84%
New Learning Technologies	3.91	4	4	1.00	73.91%	3.86	4	4	0.73	66.67%
Relevance of Science Education to Students	4.26	4	5	0.81	78.26%	4.35	5	5	0.75	85.00%
National / International Standards	3.09	3	3	0.90	34.78%	3.00	3	3	1.12	35.00%
Science Education for Economic Competitiveness	3.39	3	3	0.89	34.78%	2.95	3	4	1.07	38.10%
Reconceptualising the Purposes of Science Education	4.04	4	4	0.71	78.26%	3.76	4	4	1.22	71.43%
Globalization of the International Community	3.65	3	3	0.88	47.83%	3.48	4	4	0.98	57.14%

ROUND 2										
THEMES – FOUNDATIONS of SCIENCE EDUCATION										
	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science Education for Global Citizenship	4.00	4	4	0.85	73.91%	4.10	4	4	0.83	80.95%
Science Education for Sustainability	4.35	4	4	0.49	100.00%	4.48	5	5	0.60	95.24%
The Nature of Science	4.04	4	4	0.82	69.57%	4.05	4	4	0.86	76.19%
Science, Technology, Society and the Environment (STSE)	4.13	4	4	0.76	78.26%	4.57	5	5	0.51	100.00%
Interacting Natural and Human Global Systems	4.05	4	4	0.90	86.36%	4.00	4	4	1.00	76.19%
Scientific Skills for the 21st Century	4.30	4	4	0.63	91.30%	4.20	4	4	0.83	85.00%
Scientific Knowledge	3.61	3	3	0.72	47.83%	3.95	4	4	0.67	76.19%

ROUND 2										
THEME – GOALS of SCIENCE EDUCATION										
	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Citizenship in a Global Technological Society	4.00	4	4	0.74	82.61%	3.86	4	4	0.96	71.43%
Career-building for a Technological Society	3.61	4	3	0.78	52.17%	3.52	4	4	0.87	61.90%
Economic Competitiveness	3.30	3	4	0.82	43.48%	3.10	3	3	0.94	33.33%
Literacy in Science-Related Issues	4.35	4	4	0.65	91.30%	4.57	5	5	0.51	100.00%
Personal Character Development	3.30	3	3	0.70	26.09%	3.05	3	3	0.86	28.57%
Life-Long Learning	4.04	4	4	0.71	78.26%	4.05	4	4	0.74	80.95%

Contribute to Human Health and Well-Being	4.13	4	4	0.69	82.61%	4.24	4	5	0.89	80.95%
Training of Future Scientists	3.57	3	3	0.66	47.83%	3.29	3	3	0.78	38.10%
Develop a Deep Sense of Wonder and Curiosity	4.13	4	4	0.69	82.61%	4.33	5	5	0.80	80.95%
Pursue Progressively Higher Levels of Study	3.00	3	3	0.74	17.39%	3.19	3	3	0.98	33.33%
Sustaining Earth's Systems	4.09	4	4	0.73	78.26%	4.38	5	5	0.80	95.24%

ROUND 2

THEME –CONTRIBUTORS to a NATIONAL VISION for SCIENCE EDUCATION in CANADA

	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Note: These ratings were on a semantic differential scale from +2 to -2.										
Voices of Indigenous Peoples	1.13	1	1	0.63	86.96%	1.00	1	1	0.69	77.78%
Inter-Provincial Cooperation	1.14	1	1	0.77	86.36%	-0.11	0	0	1.33	36.84%
Cultural Diversity	0.74	1	1	1.10	73.91%	0.89	1	1	0.74	68.42%
Linguistic Diversity	0.27	0	1	0.94	45.45%	0.37	0	0	0.76	42.11%
Provincial Electoral Cycles	-0.70	-1	-1	1.13	60.00%	-0.84	-1	0	0.90	52.63%
Federal Electoral Cycles	-0.75	-1	0	1.07	55.00%	-0.67	0	0	0.84	44.44%
Control of Curriculum by Provincial Ministries of Education	-0.64	-1	-2	1.33	54.55%	-0.42	0	-2	1.26	47.37%
Physical Geography	0.32	0	0	0.84	40.91%	0.32	1	1	1.06	52.63%

ROUND 2										
ROLES and RESPONSIBILITIES in SCIENCE CURRICULUM DEVELOPMENT										
	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Ministers of Education	3.27	3	3	1.12	34.78%	3.40	4	4	1.19	55.00%
Senior Staff in Provincial Ministries of Education	2.91	3	2	1.02	30.43%	2.80	3	4	1.15	35.00%
Science Education Specialists in Ministries of Education	3.86	4	4	0.83	65.22%	3.95	4	5	1.15	70.00%
Industry Professionals	3.50	3	3	0.74	43.48%	3.35	4	4	0.99	55.00%
Faculties of Education (University)	3.95	4	4	0.65	73.91%	4.15	4	4	0.75	90.00%
College Faculty	3.77	4	4	0.69	56.52%	3.75	4	4	0.64	75.00%
Parents	2.91	3	3	0.61	13.04%	3.05	3	4	1.05	40.00%
Students	3.32	3	3	0.95	39.13%	3.35	4	4	1.09	55.00%
Science Teachers (K-12)	4.23	4	4	0.53	95.65%	4.30	4	4	0.57	95.00%
Academic Scientists	3.77	4	4	0.75	56.52%	3.75	4	4	0.72	70.00%

ROUND 2										
THEME – CONTRIBUTORS to a CANADIAN APPROACH to SCIENCE EDUCATION	COHORT 1 (N = 23)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
	Canada as a Circumpolar Nation	3.95	4	4	0.91	65.00%	3.80	4	4	0.89
Indigenous Ways of Knowing	3.82	4	4	0.85	60.87%	3.53	4	4	1.12	57.89%
Issues of Gender Equity	3.41	3	3	0.96	43.48%	2.89	3	3	0.88	26.32%
Issues of Human Rights	3.40	3	3	0.75	33.33%	3.37	3	3	1.12	45.00%
Regional Priorities	3.59	4	4	0.73	52.17%	3.50	4	3	1.10	50.00%
Relationships with Trading Partners	2.76	3	2	0.89	18.18%	2.42	3	3	1.12	10.53%
International Student Collaborations	3.55	4	4	0.96	56.52%	3.37	3	3	0.76	36.84%
Science Education for a Democratic Society	4.14	5	5	0.94	60.87%	3.83	4	3	0.99	55.56%
Career Specializations in the Sciences	3.73	4	4	0.83	56.52%	3.47	3	3	0.77	42.11%
Equity of Opportunity in the Sciences	3.50	3	3	0.96	39.13%	3.42	4	4	0.9	52.00%
Science Education for a Sustainable Future	4.64	5	5	0.58	95.65%	4.32	5	5	0.89	84.21%

Table 7: Theme Ratings for COHORTS 1 and 2 in Round 3.

ROUND 3										
THEME – GLOBAL TRENDS & SCIENCE EDUCATION (Perception of Actual Influence)										
	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science, Technology, Engineering & Mathematics (STEM)	3.75	4	3	0.79	55.00%	3.75	4	4	0.64	66.67%
Integration of Indigenous Perspectives / Knowledge	3.10	3	3	0.94	33.33%	2.86	3	3	0.85	23.81%
Developing Skills for the 21st Century	4.19	4	4	0.75	90.48%	4.30	5	5	0.80	71.43%
Science and Education for Sustainability	4.10	4	4	0.62	85.71%	3.90	4	4	0.77	57.14%
National/International Student Assessments (e.g., PISA, TIMMS)	3.60	3	3	0.82	50.00%	3.53	3	3	0.77	52.63%
New Learning Technologies	3.67	4	4	0.58	61.90%	3.76	3	3	0.77	66.67%
Relevance of Science Education to Students	3.81	4	4	0.75	35.00%	3.62	3	3	0.92	52.38%
National / International Standards	3.20	3	3	0.7	52.38%	3.60	4	4	0.94	65.00%
Science Education for Economic Competitiveness	3.57	3	3	0.87	42.86%	3.14	3	3	1.06	55.00%
Reconceptualising the Purposes of Science Education	3.52	3	3	0.93	57.14%	3.29	3	3	1.01	33.33%
Globalization of the International Community	3.52	4	4	0.87	55.00%	3.43	3	3	0.81	52.38%

ROUND 3										
THEME – GLOBAL TRENDS & SCIENCE EDUCATION										
(Desired Influence by Expert Panel)										
	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science, Technology, Engineering & Mathematics (STEM)	3.8	4	3	0.95	55.00%	3.75	4	4	0.64	66.67%
Integration of Indigenous Perspectives / Knowledge	3.48	3	3	1.03	42.86%	2.86	3	3	0.85	23.81%
Developing Skills for the 21st Century	4.52	5	5	0.68	90.48%	4.30	5	5	0.8	71.43%
Science and Education for Sustainability	4.57	5	5	0.51	100.00%	3.90	4	4	0.77	57.14%
National/International Student Assessments (e.g., PISA, TIMMS)	2.90	3	3	0.72	20.00%	3.53	3	3	0.77	52.63%
New Learning Technologies	3.76	4	4	0.94	61.90%	3.76	4	3	0.77	66.67%
Relevance of Science Education to Students	4.38	5	5	0.74	85.71%	3.62	4	3	0.92	52.38%
National / International Standards	3.00	3	3	0.86	25.00%	3.60	4	4	0.94	65.00%
Science Education for Economic Competitiveness	3.33	4	4	0.97	47.62%	3.14	3	3	1.06	55.00%
Reconceptualising the Purposes of Science Education	4.14	4	4	0.73	80.95%	3.29	3	3	1.01	33.33%
Globalization of the International Community	3.86	4	4	0.85	66.67%	3.43	3	3	0.81	52.38%

ROUND 3										
THEME – FOUNDATIONS of SCIENCE EDUCATION										
	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Science Education for Global Citizenship	-	-	-	-	-	-	-	-	-	-
Science Education for Sustainability	4.48	5	5	0.6	95.24%	4.43	5	5	0.68	90.48%
The Nature of Science	4.05	4	4	0.74	76.19%	4.10	4	4	0.70	80.95%
Science, Technology, Society and the Environment (STSE)	4.33	4	4	0.58	95.24%	4.33	4	4	0.66	90.48%
Interacting Natural and Human Global Systems	-	-	-	-	-	-	-	-	-	-
Scientific Skills for the 21st Century	4.29	4	4	0.78	90.48%	4.15	4	4	0.67	85.00%
Scientific Knowledge	3.71	4	4	0.64	61.90%	4.05	4	4	0.67	80.95%

ROUND 3										
THEME – GOALS of SCIENCE EDUCATION										
	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Citizenship in a Global Technological Society	4.00	4	4	0.84	76.19%	3.76	4	4	0.94	71.43%
Career-building for a Technological Society	3.48	4	4	0.75	52.38%	3.48	3	3	0.75	38.10%
Economic Competitiveness	3.33	3	3	0.91	42.86%	2.90	3	3	0.89	23.81%
Literacy in Science-Related Issues	4.38	4	4	0.5	100.00%	4.52	5	5	0.51	100.00%
Personal Character Development	3.33	3	3	0.58	38.10%	3.19	3	3	0.75	33.33%
Life-Long Learning	4.00	4	4	0.63	80.95%	4.00	4	4	0.77	71.43%
Contribute to Human Health and Well-Being	4.14	4	4	0.57	90.48%	4.14	4	4	0.65	85.71%

Training of Future Scientists	3.29	3	3	0.72	23.81%	3.33	3	3	0.66	33.33%
Develop a Deep Sense of Wonder and Curiosity	4.24	4	4	0.62	90.48%	4.14	4	4	0.79	76.19%
Pursue Progressively Higher Levels of Study	3.14	3	3	0.79	28.57%	3.10	3	3	0.62	14.29%
Sustaining Earth's Systems	4.24	4	5	0.77	80.95%	4.29	4	5	0.78	80.95%

ROUND 3

THEME –CONTRIBUTORS to a NATIONAL VISION for SCIENCE EDUCATION in CANADA

Note: These ratings were on a semantic differential scale from +2 to -2.

	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Voices of Indigenous Peoples	1.00	1	1	0.71	76.19%	0.80	1	1	0.77	60.00%
Inter-Provincial Cooperation	0.81	1	1	0.87	80.95%	0.45	1	1	1.36	60.00%
Cultural Diversity	0.90	1	1	0.72	76.19%	0.60	1	1	0.75	55.00%
Linguistic Diversity	0.19	0	0	0.60	-	0.30	0	0	0.73	55.00%
Provincial Electoral Cycles	-0.95	-1	-1	0.80	76.19%	-0.90	-1	-1	0.72	70.00%
Federal Electoral Cycles	-0.52	-1	-1	0.68	52.38%	-0.55	0	0	0.83	45.00%
Control of Curriculum by Provincial Ministries of Education	0.05	0	-1	1.36	-	-0.40	-1	-1	1.31	60.00%
Physical Geography	0.20	0	0	0.62	-	0.15	0	0	0.81	50.00%

ROUND 3**ROLES and RESPONSIBILITIES in SCIENCE CURRICULUM DEVELOPMENT**

	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Ministers of Education	3.48	3	3	1.08	42.86%	3.38	4	4	1.28	52.38%
Senior Provincial Officials in Ministries of Education	3.33	3	3	0.91	42.86%	3.43	4	4	1.16	52.38%
Science Education Specialists in Ministries of Education	4.10	4	4	0.77	76.19%	3.90	4	4	1.09	71.43%
Industry Professionals	3.43	3	3	0.81	42.86%	3.48	4	4	0.93	57.14%
Faculties of Education (University)	4.05	4	4	0.8	71.43%	4.33	4	5	0.73	85.71%
College Faculty	3.67	4	3	0.86	52.38%	3.95	4	4	0.80	66.67%
Parents	2.62	3	3	0.86	9.52%	2.76	3	3	1.14	28.57%
Students (K-12)	3.10	3	3	0.83	33.33%	3.00	3	3	1	33.33%
Science Teachers (K-12)	4.29	4	4	0.64	90.48%	4.24	4	4	0.62	90.48%
Academic Scientists	3.67	3	3	0.80	47.62%	3.62	4	4	0.86	57.14%
Aboriginal Elders and Knowledge Keepers	3.62	4	4	0.86	57.14%	3.48	4	4	0.87	57.14%
Concerned Citizens (Conflict Free)	2.52	2	2	0.68	9.52%	2.86	3	3	0.85	23.81%
Non-Academic Scientists	2.95	3	3	0.80	23.81%	3.14	3	3	0.85	33.33%
Science Communicators (e.g. media, writers)	2.33	2	2	0.91	9.52%	2.86	3	2	0.85	28.57%
Labour Organizations	2.05	2	2	0.86	4.76%	2.33	3	3	1.11	14.29%
Provincial Roundtable for All Stakeholders	3.33	3	3	1.03	44.44%	3.13	3	3	1.13	40.00%

ROUND 3**THEME – CONTRIBUTORS to a CANADIAN APPROACH to SCIENCE EDUCATION**

	COHORT 1 (N = 21)					COHORT 2 (N = 21)				
	Mean	Median	Mode	S.D.	Consensus Level	Mean	Median	Mode	S.D.	Consensus Level
Canada as a Circumpolar Nation	3.62	4	4	0.67	61.90%	3.67	4	4	1.06	57.14%
Indigenous Ways of Knowing	3.67	4	4	0.86	61.90%	3.40	3	3	1.05	45.00%
Issues of Gender Equity	-	-	-	-	-	-	-	-	-	-
Issues of Human Rights	3.30	3	3	0.8	40.00%	3.45	4	4	1.10	55.00%
Regional Priorities	3.67	4	4	0.80	60.00%	3.52	4	4	0.98	52.38%
Relationships with Trading Partners	-	-	-	-	-	-	-	-	-	-
International Student Collaborations	3.42	4	4	0.61	47.37%	3.19	3	3	0.81	28.57%
Science Education for a Democratic Society	4.24	5	5	0.89	80.95%	4.05	4	5	1.00	65.00%
Career Specializations in the Sciences	3.43	3	3	0.75	38.10%	3.43	3	3	0.75	38.10%
Equity of Opportunity in the Sciences	3.60	3	3	0.75	45.00%	3.52	4	4	0.98	52.38%
Science Education for a Sustainable Future	4.64	5	5	0.58	95.65%	4.32	5	5	0.89	84.21%

Chapter 6: Data Collection and Analysis II

This chapter will address the results of the three rounds of the Delphi study and be organized around the research questions. Attention, however, will be given to analysis and interpretation of results from the individual rounds of the Delphi. This was an aesthetic decision since Round 1 and subsequent rounds were treated so differently in the conduct of the study. Round 1 comprised lengthy narratives from participants who were responding to four large-scale general questions. Rounds 2 and 3 involved participant ratings (with statements of justification) of the themes emerging from Round 1. It is hoped that this choice will not interrupt the flow of ideas for the reader nor permit synergies and opportunities to be lost in what could be a more multivariate approach to the data analysis. The modified policy Delphi research methodology provided a consistently rich and potent set of results across the three rounds. The stratigraphy available to the researcher could easily provide for more substantive and discrete analysis from the immense data sets generated in the study, but space limitations are a constraint. Nevertheless, the efforts of the expert panel have resulted in a broad consensus in a number of key areas thought by the expert panel to significantly impact the future of science education in Canada. Alternatively, there are many areas which are contested and sources of visible disagreement are also readily found. This summary will focus particularly on those themes which generated significant levels of consensus (i.e., $\geq 70.00\%$ and $S.D. \leq 0.70$) in addition to a smaller sub-set of themes where the level of consensus appears to be

somewhat more problematic to interpret based on descriptive statistics alone. In all cases, however, anecdotal comments from the panel will serve to illuminate, define, or provide key insights into certain of the themes.

In the previous chapter, a series of tables provided a general overview of the emerging consensus/dissensus positions across each of COHORT 1 and COHORT 2 independently. For the summary of results developed in this chapter, the cohorts will be intentionally combined as though the expert panel behaved in cooperation as a single entity. In doing so, the iterative Delphi process of inquiry can be considered to have echoes of, and some similarities to, a series of deliberative conferences among the expert community in science education (Orpwood, 1981). The controlled feedback provided to each cohort between Delphi rounds served the purpose of “all voices being heard from”, and this is a critical dimension of deliberative inquiry (Aikenhead, 1999). Given the levels to which the inter-round summaries were examined by members of the panel (cf. Figure 13, page 167), there is a large measure of confidence that not only were participants’ voices in the study being heard, but the expert panel members were listening, and listening intently.

Before I begin the detailed analysis of the data in light of the research questions, it is useful to re-present them here together with the study’s objectives:

Primary Research Question (PRQ)

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 the post-Pan Canadian Framework period?

Ancillary Research Questions (RQx)

1. What trends and conditions – both domestic and international – will serve to initiate and have defining influence upon future science curriculum change in Canada? (RQ1)
2. What characterises consensus (or 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? (RQ2)
3. What characterises 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? (RQ3)

The principal objectives of the study, drawing on the stimulus of the research questions, are as follows:

- a. To give definition to and describe in some detail the system conditions that will initiate and influence development of science education in Canada;
- b. To determine and describe the theoretical foundations and goals for the 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.

Data Analysis of Delphi Round 1: Research Question RQ1

Seed 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.

The members of the expert panel were provided a four-week period to address this and three other seed questions that provided an open atmosphere to compose at length. The wording of the seed question was intentionally wide open and free of form which is typical in a modified Delphi approach. In order to do justice to the significance of the many written responses in all of the three rounds of the Delphi (and the *post-hoc* semi-structured interviews), this chapter will contain many verbatim quotes from each of these sources which act to support the emergence of the themes in the study. These contributions can be viewed as either representative of many similar opinions from members of the panel, striking language with respect to how ideas are presented, or both.

Global Trends Affecting the Future of Science Education

Research Question Addressed – RQ1

The opening free-form Question #1 in the questionnaire instrument offered the members of the expert panel to project their thinking forward to the year 2030 (a generation) and provide personal and professional insights into what they believed would be the significant national and international (global) trends that would be the potential or actual drivers of science education. Given the wide range of possibilities in response, it is not possible in the results summary here to provide an exhaustive selection of participants' thoughts. The trends that generated the largest proportions in terms of textual references based on reflexive and iterative coding included:

- 1) Globalisation influences (at 29.97%)³³
- 2) Science-Oriented Skills for the 21st Century (at 13.41%)
- 3) Science Education and Sustainability (at 11.40%)
- 4) New Technologies for Learning (at 10.94%)
- 5) The Relevance of Science Education for Students (at 10.32%)
- 6) Science, Technology, Engineering and Mathematics (STEM) (at 7.40%).

³³ The percentages indicate the number of references in the coding as a proportion of all references in the question responses. For example, 29.97% implies that almost 30% of all responses to Question #1 included references to ideas, concepts, realities, etc. that could be applied to “globalisation”.

Globalisation Influences

In terms of what was identified in the research as being indicative of “globalisation influences”, these were generally aligned with the following: (1) economic competitiveness internationally; (2) international science education – “global scope learning” and international schools of science and mathematics education; (3) the development of national-level or possibly international science education standards; (4) neo-liberalism in the political and economic spheres (in the manner defined by Bloch, 2014), and; (5) national and international large-scale science assessments such as PISA, TIMSS, PCAP, PIRLS, etc. What follows are samples of commentary which are particularly representative of the global trends identified in Round 1 responses³⁴.

According to a teacher-educator in a Canadian university faculty of education (1055TE), there are certain trends that could have “high impact magnitude” for science education:

“...greater consideration of sustainability issues and perspectives in school education with the possible impact on the nature of science education: revisions of science curricula to give consideration to those issues and perspectives (high impact magnitude); greater societal concern with countries' rankings in large-scale international standardized tests (test results are and will continue to be interpreted by the media, and a good part of the public, as an indicator of a country's economic competitiveness with a possible impact on the nature of science education: greater focus on "basics"; short-term increased resource

³⁴ The alphanumeric codes refer to individual respondents from among the expert panel. The first digit identifies either COHORT 1 or COHORT 2. The two-letter identifier provides the panel member's professional affiliation. For a more detailed explanation of the codes, refer to the methodology chapter (Chapter 4).

allocation to science education with greater pressure to limit inquiry-based learning in science education (high impact magnitude).”

There was a significant focus on the role of science and technology education as these affect the ability of Canada’s youth to be positioned competitively in a globalised economic structure. A generation ago, the state of Canada’s international position was generally not a serious consideration. This statement was provided by a panel member with a lengthy baseline of experience in educational policy-making and analysis and demonstrates that the world has definitely changed in this regard (2085PE):

“Growth of economic globalisation, growth of the economic impact of science and technology (S&T), and the consequent growth of the importance of S&T education. Thirty years ago, when the Science Council of Canada published "Science for Every Student", the state of science education in Canada relative to other countries was not considered. Now, the interest in studies such as TIMSS, PISA, and the research on science education around the world reflects the growing awareness that Canada (and all its provinces and territories) live in an increasingly competitive global society and that the quality of S&T education today - at elementary, secondary and post-secondary levels - will impact Canada's economic position tomorrow. This trend will become more sharply defined and have an increasing impact, in my view.”

A similar view, but related more to innovation, was provided by a panel member who works directly in the public understanding of science. Their point of view resonates with recently developed foundations for renewal of the K-12 education system in one Canadian province (Alberta). This renewal effort has identified the “spirit of entrepreneurship” as one of the system’s cornerstones, and foresees that the formal education system has a responsibility to encourage thinking and learning about innovation at a very early age.

“With the rapid rise of 'developing' countries' economies there is growing attention to the importance of 'innovation' for economic prosperity, and the role of science and technology in driving innovation. Unfortunately, most attention is currently at the postsecondary level with respect to education for innovation. However, if the argument about the importance of developing stronger interest and participation in science starting in the K-12 stream, then science education could become seen as more important than it is now.”

(Panel member 1098PU)

Among the trends identified as potentially having effect, there emerged the Science, Technology, Engineering, and Mathematics (STEM) movement, which is principally a derived curriculum framework from an interpretation of the U.S. National Research Council (NRC, 2012) framework and very much evident in the Next Generation Science Standards. One science teacher-educator from a western Canadian faculty of education put this trend in perspective:

“Science, Technology, Engineering and Mathematics (STEM) is a Kindergarten through Grade 12 school science and science education initiative for college and the workplace. It maintains that countries with "scientifically proficient workers / work force" are likely to fare better. There will be emphasis on inclusiveness with attempts to increase the successful participation of minorities - particularly First Nations, Metis, and Inuit in Canada.” (2054TE)

And this from a science educator, now working internationally but with strong ties to Canada:

“Unfortunately, neoliberalism has been the most significant influence on science education internationally in the past decade and this will continue to have influence despite the desire many may have for science education to be informed by more palatable influences. It is well documented that despite all the advocacy for 'new developments' in science education by, especially, science education scholars, we fail to see inroads in these developments because science education ends up being merged with the collective education agenda which is largely influenced by government policy.”
(2030TE)

Science-Oriented Skills for the 21st Century

The research provided certain future influences as being indicative of a relationship to “skills for the 21st century” or “21st century learning”³⁵. Such thinking was provided by about one-fourth of the expert panel and was generally aligned with the following: (1) common-core type standards models; (2) competency-based learning; (3) critical thinking; (4) information and communications’ technologies literacy; (5) access to and the synthesis of available online information, and; (6) new learning technologies which will (and are already) creating entirely new learning environments. What follows are samples of commentary which are particularly representative of what was

³⁵ Recent publications such as the Equinox Blueprint: Learning 2030 (Waterloo Global Science Initiative, 2014) available online at: <http://wgsi.org/equinox-summit/equinox-summit-learning-2030> ; Alberta Education. “Competencies for 21st Century Learning”. <http://education.alberta.ca/teachers/aisi/themes/21-century.aspx> ; the Partnership for 21st Century Skills (2007), available online at: <http://www.21stcenturyskills.org>, and; Fullan, M, (2013). “*Great to Excellent: Launching the Next Phase of Ontario’s Education Agenda.*”, available online at: http://www.michaelfullan.ca/wp-content/uploads/2013/09/13_Fullan_Great-to-Excellent.pdf have shaped the definitions of respondents’ views on 21st century skills and/or competencies.

frequently referred to as a 21st century skills emphasis. Note the significance of the manner in which these “skills” seemed to be ill-defined and that the movement has been described by some members of the panel as congruent with sloganism in a post-millennial re-packaging of outdated rhetoric:

“Globally there is a push to assess the development by 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 discuss and how this looks in classrooms. 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, all are talking about these skills but are defining them slightly differently and / or calling them 'competencies'.” (1098PU)

Science Education and Sustainability

The research demonstrated that the theme of science and sustainability was among the leading themes in terms of overall textual references from Question #1, inviting 75 distinct coded references from half of the expert panel. In addition, this theme also invited the largest amount of data to be coded in terms of word count. There was no other theme in the study which would come close to the depth, breadth, passion, and variety that was observed from this theme. As a consequence, there is an opportunity to provide an indication of the richness of the commentary, since many now view sustainability as being at the interface of most aspects of the enterprise of science education. Here are some perspectives from a K-12 science teacher:

“Concern for, and curiosity about, the environment including climate sciences, and humanity’s interaction with its systems. The emergence of new areas of study in climate and the environmental sciences means that both of these fields are still in periods of ‘negative discovery’. It will be vital for teachers to be as informed about the new emerging questions as they are about the inaccuracies of human thinking in the past. It will be important to inspire students with curiosity and a sense of purpose rather than a sense of hopelessness in the lot they have been handed by their ancestors. They will be the ones to develop strategies for adapting to and mitigating environmental changes and disasters.” (1099ST)

In an echo of what many participants had to say about the “disciplinary” nature of science education, a science media specialist had this to say about how the “silo effect” in education may be a significant barrier to understandings about systems and the interrelatedness of the sciences for the sake of sustainability:

“It should not be surprising that science and sustainability is of essence to be integrated into other disciplines. 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. (2001PU)

Also at the core of educating for sustainability – from a science educator perspective – are the considered importance of active, democratic citizenship through an emphasis on students involving themselves with socio-scientific issues (SSI) as a way to increase the action potential among students. Here are a series of

thoughts on this from an education faculty member (1054TE) who views issues of sustainability as now being at the core of SSI-approach science education:

“Education for citizenship... the issue of educating students to become active participants in society, who are capable of making informed decisions on socio-scientific issues (SSI) seems to me to be a widespread call for science educators around the world. This trend necessarily implies curricular and pedagogical changes; it encompasses not only the notion of social critique and social change as inherent to science education, but also a new approach to pedagogical practices, which will ensure students have the opportunity to develop skills and attitudes needed to be able to fully participate in SSI debates not only in the classroom, but especially in society at large.

Within this trend, I also identify a particular concern with sustainability issues (which I identify as naturally connected to citizenship)... I emphasize the notions of (a) an interdisciplinary approach to science and SSIs and (b) the skills and attitudes students need to develop to be able to successfully participate in a science classroom where education for citizenship takes place. The call for interdisciplinary content in science education is certainly not new, but it is renewed in the case of the SSI approach to teaching science in schools. (1054TE).

New Technologies for Learning

In terms of what was identified in the research as being indicative of “emergence of new technologies for learning”, the thinking of the expert panel members was generally aligned with the new realities that have, are, and will be influenced by a continuing technological pace of development that would not have been imaginable 20 or 30 years ago. This was an area in the panel members’

dialogue that had the most diverse set of unknowns among the experts in terms of their forecasting in the Delphi. Since we can only imagine what the new learning technologies will be (or phrased another way, new technologies for learning) it is of interest to view some of the commentary that came forward:

“There may well be room for schooling at home (not necessarily home-schooling, but that too) since physically convening kids to work online may well be pointless and costly. Physical groupings of students may be limited to laboratory settings. In fact, the more that computer simulations are used in science, the more important it will become for science learners to see the actual phenomena in real life!” (1016PB)

A science education specialist working within a provincial department of education placed an emphasis on how the digital revolution and social media have already placed an emphasis on information acquisition and the ability to assess and process that information with precision:

“One trend would be the rapid digitalization of our world. Most students can now have rapid access to incredible amounts of information, can use software or apps that permit the collection of all sorts of data, and can then share ideas and data using social media platforms. The ability to access information and then act on it appropriately should shift the emphasis in science education away from the transmission of a body of facts toward evaluating information and data.” (1037PB)

The Relevance of Science Education for Students

One of the real surprise trends that emerged in the Round 1 responses was the degree to which the expert panel took advantage of what can be variously

described as the ‘relevance of science education’, ‘student engagement in science’, or ‘science education with a purpose in mind’(Jenkins & Pell, 2006); Metz *et al.*, 2007; Millar & Osborne, 1998; Osborne & Collins, 2001). More than half of the expert panel members had some thinking to offer on this theme, and it has provided an important opportunity to bring forth the increased importance of Canada’s indigenous peoples’ and their relationship to science education in the Canadian context. A Cree elder and science educator among teachers in a northern Canadian setting provided these perspectives:

“The involvement of indigenous peoples in science education is paramount. Indigenous philosophies, ontologies, methodologies, and pedagogical practices need to be a part of the development of science education frameworks. This is essential if we are to foster greater Aboriginal student engagement in the sciences. . . . these are 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 scientific communities on an equal footing.” (2042TE)

An influential science media specialist expressed both concern for, and opportunity with, the emergence of the rapid, individualised flow of information to the end-user and the associated dis-engagement with the natural world as a source of play and information:

“There is a trend towards research on the internet and the sharing of information via social media. This is where our young people are maximizing their engagement, and this is where science has to meet with them. While this

provides tremendous access to global information, the challenge for the student (and public) is to tell the difference between science based on evidence, pseudo-science such as Intelligent Design and creationism, and other sources of online science information that can disguise their intentions extremely well. We need re-engagement.” (2062PU)

A very intriguing set of arguments which I would describe as advocating “play-based learning” approaches in science was presented by a Canadian particle physicist. Pay close attention to what is said about the role of mathematics in science teaching and learning:

“What should happen is that kids be exposed to the wonders of science and trained to think and play like a scientist does. That’s right. . . .at play with science. Lots of exploration, lots of experimentation, lots of play, and start doing so from infancy. We all know kids are naturally curious and love that kind of stuff, so we should double and triple down and give them as much as they want and make it as fun and exciting as possible. If they can keep that joy and interest into their teens, science education in the high schools will be no problem in terms of relevance. But. . . . Let me warn you – leave out the math – and this is coming from a physicist (me). Leave the math completely out of it, except for perhaps graduating students going on university to specialize. It’s killing off their interest too early. Very, very few people need to know the equations of, for instance, Newton's Laws, though what I would claim is that everyone ought to have a feeling for what these laws actually mean.” (1051PS)

Science, Technology, Engineering and Mathematics (STEM)

For many among the expert panel in the Delphi, STEM education is not simply a trend but the new reality – and one particularly tied to current U.S. influences in science education. It is thought (by virtue of a scan of almost 50 codings directly referencing STEM education that it shares connections with a

number of other themes that are examined in the data related to global trends affecting science education. The Science, Technology, Engineering and Mathematics (STEM) theme which emerged from 25 participants in the Round 1 responses included references to: (1) its existence as a recent re-conceptualization of the core approach to the teaching and learning of science; (2) a departure in the foundations of science education away from STSE as a planning approach, and; (3) a distinct realignment from the former emphasis on science for citizenship to science for skills development towards employment and especially for innovation and leveraging the 21st century economy. It was a consideration that many ‘future-oriented employment profiles will require a significant personal background in STEM education, and that the direct teaching of engineering and design principles is important to international competitiveness in a globalized economy and for the prospects of science and technology as ‘drivers of the innovation’ that can lead to a prosperous economy. As was pointed out explicitly in one of the interviews:

“There should be a national vision for STEM learning, with a STEM Secretariat at the federal level which includes initiatives in the skilled trades, colleges and universities.” (interview, 1098PU, May 1, 2014).

STEM is also viewed by many in the expert panel as foundational to the future architecture of science curriculum, teaching, and learning such that it provides a broadly acceptable national vision for science education and a platform upon which diverse career opportunities across all post-secondary pathways can be constructed by students. Interdisciplinary approaches that exist at the interface

of STEM and the arts (as STEAM) were viewed as a point of entry among disenchanted or reluctant generalist teachers of science. There is mention of the science-proficient worker that will participate in an inevitably globalised future which will be characterized by increasing dependence upon the influence, the importance of, and the affordances provided by engineering, biotechnology, and other applied science fields.

Data Analysis of Delphi Rounds 2 and 3: Research Question RQ1

Following the completion of Round 1 and the distribution of controlled feedback to the participants of both cohorts, the members of the expert panel were provided a two-week period to address this seed question in a completely different way - through the provision of rating scales based on the emergent themes of Round 1. This second round commenced the *semi-quantitative* segment of the research methodology as outlined fully in Chapter 4. In both of Rounds 2 and 3, participants responded to a 36-item questionnaire which captured data which would eventually provide the basis for assessing the experts' opinions across all the research questions. The first of these (RQ1) related to expert panel opinion on the 47 themes developed out of the previous round. Since RQ1 particularly references Global Trends Affecting the Future of Science Education to 2030, the summary in this section is confined to an assessment of the 11 themes which characterized responses aligned solely with this question. The 11 themes assessed in the rating scales were:

- 1) Science, Technology, Engineering & Mathematics (STEM)
- 2) Integration of Indigenous Perspectives / Knowledge
- 3) Developing Skills for the 21st Century
- 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

Participants were requested to rate the relative importance of each theme related to global trends in science education – often with a required justification statement. The ratings were done twice: first in accordance to the level of influence each panel member *perceived* it would have in the education system, and then a second time assessing the themes in accordance with what the *desired influence* it would have in their ideal system of education. Table 9 below provides the results of the ratings after Round 3 was completed.³⁶ Unlike the presentation of ratings in Chapter 5, the results here are reported as aggregates across the entire expert panel – COHORT 1 and COHORT 2. This is intentional and the rationale was provided at the opening of this chapter.

³⁶ **Note:** For all tables in this chapter, strong POSITIVE CONSENSUS positions (acceptance) are highlighted in **BLUE**. Strong NEGATIVE CONSENSUS positions (rejection, majority not agreeing) are highlighted in **RED**. DISSENSUS (contested positions with polarised opinion) are identified in **ORANGE**.

Table 8: Combined ratings and consensus levels for RQ1 – Global Trends Affecting the Future of Science Education in Canada.

COMBINED CONSENSUS - COHORTS 1 & 2					
THEMES – GLOBAL TRENDS & SCIENCE EDUCATION					
(Perceived Influence According to Expert Panel)	COHORTS 1 & 2 (N = 42)				Consensus Level
	Mean	Median	Mode	S.D.	
Science, Technology, Engineering & Mathematics (STEM)	3.75	4.0	4	0.71	60.98%
Integration of Indigenous Perspectives / Knowledge	2.98	3.0	3	0.90	28.57%
Developing Skills for the 21st Century	4.24	4.0	4	0.77	80.95%
Science and Education for Sustainability	4.00	4.0	4	0.7	71.43%
National/International Student Assessments	3.56	3.0	3	0.79	51.28%
New Learning Technologies	3.71	4.0	4	0.67	64.29%
Relevance of Science Education to Students	3.71	4.0	4	0.83	57.14%
National / International Standards	3.40	3.0	4	0.84	50.00%
Science Education for Economic Competitiveness	3.36	3.0	3	0.98	53.66%
Re-conceptualizing the Purposes of Science Education	3.40	3.0	3	0.96	38.10%
Globalization of the International Community	3.48	4.0	4	0.83	54.76%

COMBINED CONSENSUS - COHORTS 1 & 2					
THEMES – GLOBAL TRENDS & SCIENCE EDUCATION					
(Desired Influence by Expert Panel)	COHORTS 1 & 2 (N = 42)				Consensus Level
	Mean	Median	Mode	S.D.	
Science, Technology, Engineering & Mathematics (STEM)	3.73	4.0	3	0.93	62.50%
Integration of Indigenous Perspectives / Knowledge	3.38	3.0	3	1.06	45.24%
Developing Skills for the 21st Century	4.39	5.0	5	0.70	87.80%
Science and Education for Sustainability	4.50	5.0	5	0.63	92.86%
National/International Student Assessments	2.90	3.0	3	0.85	20.51%
New Learning Technologies	3.81	4.0	4	0.83	64.29%
Relevance of Science Education to Students	4.31	4.0	5	0.78	85.71%
National / International Standards	3.13	3.0	3	0.98	30.77%

Science Education for Economic Competitiveness	3.15	3.0	4	0.94	39.02%
Re-conceptualizing the Purposes of Science Education	3.95	4.0	4	0.99	71.43%
Globalization of the International Community	3.71	4.0	4	1.04	59.52%

Interpretation of the Data – Global Trends and Science Education - Rounds 2 and 3

Research Question Addressed – RQ1

Significant consensus was achieved for two important influences expected to predominate for science education in Canada: the perceived need for the development of 21st century skills (consensus level = 80.95%) and science and education for sustainability (consensus level = 71.43%). When the expert panel re-rated the same influences – but this time as what they viewed as their desired state of influence – more significance was placed on these in terms of the importance of what *should* occur in systems of education: the development of 21st century skills (consensus level = 87.80%) and science and education for sustainability (consensus level = 92.86%). An increased level of consensus on the relevance of science and education for sustainability was strongly driven in Round 3 by the opinions of COHORT 2 – the more experienced cohort. Alternatively, the increased level of consensus on the development of 21st century skills was driven in Rounds 2 and 3 by significant consensus from COHORT 1 – those who are overwhelmingly at early- to mid-career in science education or a professional discipline allied with the sciences. Moreover, two other trends emerged in terms of *desired influences*, these being: the relevance of science education to students (consensus level = 85.71%) and re-conceptualizing the purposes of science education (consensus level = 71.43%). An increased level of consensus on the relevance of science education was strongly driven in Round 3

by the opinions of COHORT 2 – the more experienced cohort. Both cohorts were similarly positioned with respect to consensus on the re-conceptualizing of the purposes of science education.

There were two notable negative consensus positions (rejection) emerging from Rounds 2 and 3: one was related to an expectation that the integration of Aboriginal/Indigenous perspectives in science education would not hold significance in the next 15-20 years. This situation survived all rounds of the Delphi but was by no means absent from the commentary of participants nor was it considered unimportant to the character of a Canadian approach to science education as will be described later in this chapter.

Approximately half of the expert panel was of the opinion that national and international standardized assessments (e.g., PISA, PCAP, etc.) would have some degree of importance as influences on future trends in science education. However, when asked about the degree to which such influences *should* have some importance, the voices were rather different. The general consensus was a significant *rejection* of the role that such assessments should have on influencing the directions of science education in the coming years. This negative consensus was directed more from the opinions from panel members in COHORT 1 than in COHORT 2. This was, for me, an important and significant finding given the current climate of Canadian education system monitoring and the manner in which numerical adjudications of student achievement are not viewed merely as proxies for measuring the health of education systems. Such assessments have

become an international pre-occupation and are stimulating a lively debate about how educational success is measured.

Data Analysis of Delphi Round 1: Research Question RQ2

Seed 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 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. The largest proportions of textual references based on the coding included the following in the category of “Foundations for Science Education”:³⁷

- 1) Science, Technology, Society and the Environment (STSE) (at 34.56%)
- 2) Science Education for Sustainability (at 17.45%)
- 3) Scientific Knowledge (at 9.42%)
- 4) Science Education for Global Citizenship (at 6.10%)
- 5) Scientific Skills for the 21st Century (at 5.75%)
- 6) Interacting Systems and Systems Thinking (at 4.01%)
- 7) The Nature of Science (at 4.01 %)

³⁷ The percentages indicate the number of references in the coding as a proportion of all references in the question responses. For example, 34.56% implies that almost 35% of all responses to Question #2 included references to ideas, concepts, realities, etc. that could be considered appropriate to foundations or goals in science education.

The free-form Question #2 in the questionnaire instrument also 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 goals of science education in Canada. The largest proportions in terms of textual references based on reflexive and iterative coding included the following in the category of “Goals”:³⁸

- 1) Literacy in Science-Related Issues (at 51.61%)
- 2) Develop a Deep Sense of Wonder and Curiosity (at 19.35%)
- 3) Personal Character Development (at 19.35%)
- 4) Democratic Citizenship in a Global Technological Society (at 18.55%)
- 5) Sustaining Earth's Systems (at 18.55%)
- 6) Career-building for a Technological Society (at 11.29%)
- 7) Economic Competitiveness (at 8.06%)
- 8) Life-Long Learning (at 8.06%)
- 9) Training of Future Scientists (at 7.25%)
- 10) Pursue Progressively Higher Levels of Study (at 7.25%)
- 11) Contribute to Human Health and Well-Being (at 5.64%)

Since the anecdotal comments from participants with respect to the goals of science education across both Rounds 1 and 2 are quite consistent and mutually

³⁸ The percentages indicate the number of references in the coding as a proportion of all references in the question responses. For example, 11.29% implies that about 1/10 of all responses to Question #2 included references to ideas, concepts, realities, etc. that could be considered appropriate to goals in science education.

representative for each of these seven themes emerging from the Round 1 questionnaire, they will be addressed in the next section only.

Data Analysis of Delphi Rounds 2 and 3: Research Question RQ2

Research question (RQ2) was also related to expert panel opinion on the 47 themes developed out of the Round 1 experiences of the expert panel. Since RQ2 particularly references the foundations and goals of science education in Canada, the summary in this section is confined to an assessment of the 18 themes which characterized responses aligned with this question. The 18 themes assessed in the questionnaire rating scales were as follows³⁹:

The Foundations of Canadian Science Curriculum (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
- 6) Scientific Skills for the 21st Century
- 7) Scientific Knowledge

The Goals of Canadian Science Education (11 themes)

- 1) Democratic Citizenship in a Global Technological Society
- 2) Career-building for a Technological Society

³⁹ The questionnaires for Rounds 2 and 3 can be viewed in Appendices 'D' and 'E' respectively.

- 3) Economic Competitiveness
- 4) Literacy in Science-Related Issues
- 5) Personal Character Development
- 6) Life-Long Learning
- 7) Contribute to Human Health and Well-Being
- 8) Training of Future Scientists
- 9) Develop a Deep Sense of Wonder and Curiosity
- 10) Pursue Progressively Higher Levels of Study
- 11) Sustaining Earth's Systems

Interpretation of the Data – The Foundations and Goals of Science Education to 2030 - Rounds 2 and 3

Research Question Addressed – RQ2

Participants were requested to rate the relative importance of each theme related to the foundations and goals of Canadian science education – often with a required justification statement. The ratings were done twice: first in Round 2 with the themes precisely as these emerged from the Round 1 qualitative analysis, and then a second time in Round 3 using the same rating scales but with some variations. The variations introduced in Round 3 were principally of two types: (1) the removal of certain themes due to very low ratings in Round 2, and; (2) the introduction of new variables for certain of the rating scales in response to sufficient comments from the expert panel during Round 2. Neither of these interventions materially affected the study’s methodology and are considered typical in a modified Delphi study (Hasson & Keeney, 2011; Linstone & Turoff, 2011; Shelton, 2010). Table 9 below provides the results of the ratings for the

foundations of Canadian science education after Round 3 was completed.⁴⁰ In a similar fashion to what was presented for the trends affecting science education (this chapter) the results here are reported as a single expert panel – COHORT 1 and COHORT 2 - combined as at the close of the Delphi. Where considered appropriate, written anecdotes are provided that lend clarification to, justifications for, or support for positions taken among members of the expert panel.

Table 9: Combined ratings and consensus levels for RQ2 – the Foundations of Science Education in Canada.

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

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

⁴⁰ **Note:** For all tables in this chapter, strong POSITIVE CONSENSUS positions (acceptance) are highlighted in **BLUE**. Strong NEGATIVE CONSENSUS positions (rejection, majority not agreeing) are highlighted in **RED**. DISSENSUS (contested positions with polarised opinion) are identified in **ORANGE**.

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

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

- (1) Science Education for Sustainability (consensus level = 92.86%);
- (2) Science, Technology, Society and the Environment (STSE)
(consensus level = 92.86%);
- (3) Scientific Skills for the 21st Century (consensus level = 87.80%);
- (4) The Nature of Science (consensus level = 78.57%) and;
- (5) Scientific Knowledge (consensus level = 71.43%)⁴¹ .

The last of these in the list – scientific knowledge – would not have reached the minimum level of consensus if it were not for the strong views on its incorporation from COHORT 2 which as a group held a consensus level of 76.19% in Round 2 and stabilized at 80.95% in Round 3 on this foundation area. At no time did COHORT 1 rate scientific knowledge as 'very important' (4) or 'essential' (5) in the ratings beyond a 61.90% level of consensus. This is perhaps

⁴¹ Note: The characterisation of what constitutes "scientific knowledge" is described later in this chapter.

indicative of differences between the cohorts in what constitutes ‘scientific knowledge’ or how the term is defined.

When a comparison is made between the Round 2 responses (Chapter 5) and what is presented here, it will be noted that certain of the foundations areas were changed from Round 2 to Round 3. Based on participant requests, the foundation areas of Science Education for Global Citizenship and Interacting Natural and Human Systems were collapsed under the more comprehensive foundation of Science Education for Sustainability. This area – in the coded data – subsumed and incorporated interests such as the sustainability sciences, education for sustainable development, education for sustainability, and sustainability education.

Participants were requested (and required in the case of rating the foundations) to provide justification statements for their positions. For some there was real difficulty in determining which foundations have greatest importance, or, a sense that isolating foundation areas was no less of a problem than compartmentalizing the science disciplines. That is, the identification of foundation areas was a constraint in the realisation of a completely new vision for the purposes of science education. In this regard, here is a representative comment from a science faculty *emeritus*:

“I must admit that these foundations are a source of difficulty for me - I have attempted to emphasize my views on the importance of sustainability sciences which I would have thought should be taught across the disciplines in order to retain its essential usefulness. I don't readily see an avenue for expressing that through the foundations listed (by the panel's efforts). Adding

to my difficulty is my view that the first four foundations (global citizenship, STSE, interacting systems, and systems thinking) are all related - almost all part of the same thing - how can one educate for sustainability without an understanding of system interactions, the relevant scientific knowledge, and systems thinking... and isn't global citizenship a purpose of educating for sustainability? There is really only one foundation.” (2067PE)

As one panel member observed (2088PE), one who has spent a lengthy career in the pharmaceutical sciences, the umbrella of sustainability as a foundation includes virtually all of the traditional foundation areas of Canadian science curriculum since the advent of the pan-Canadian Framework in the mid-1990s:

” 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. (2088PE)

One teacher of physics echoed this view, and recognised that what has been considered as STSE in curriculum now has a place in the broader context of science education for sustainability. This view was expressed in the following manner:

“I placed science for Global Citizenship and for Sustainability as having the primary importance, but these foundations have to take into account systems thinking, STSE, knowledge, 21st Century Skills, and the Nature of Science. I also wasn't sure about the difference between the Global Citizenship and Sustainability and STSE. I only placed Science Knowledge as having some importance because it must be there when you're studying science, but as soon as it becomes a major foundation, it opens the door to more traditional ways of teaching science.” (2095ST)

The goals of science education, as defined for the expert panel members in the Round 2 and Round 3 questionnaires, were described in the following manner: *“For the purposes of this study, 'goals' refers to the larger-scale desired outcomes of a general science education that usually define the overall purposes of conducting science education in the Canadian provinces. In this instance, the goals are confined to what could define the K-12 system of science education; these goals are intended to serve all avenues of adult life.”* Therefore, in assessing the importance for inclusion in Canadian science education, the goals constitute the “end-rationale” of the enterprise of science education more generally and K-12 (formal) science education in particular. The goals should assist any Canadian in answering the fundamental question, “What is the purpose of science education in Canadian schools?” Table 11 below provides the results of the ratings for the goals of Canadian science education after Round 3.

Table 10: Combined ratings and consensus levels for RQ2 – the Goals of Science Education in Canada.

COMBINED CONSENSUS - COHORTS 1 & 2					
THEME – GOALS of SCIENCE EDUCATION	COHORTS 1 & 2 (N = 42)				Consensus Level
	Mean	Median	Mode	S.D.	
Citizenship in a Global Technological Society	3.88	4.0	4	0.89	73.81%
Career-building for a Technological Society	3.48	3.0	3	0.74	45.24%
Economic Competitiveness	3.12	3.0	3	0.92	33.33%
Literacy in Science-Related Issues	4.45	4.0	4	0.50	100.00%
Personal Character Development	3.26	3.0	3	0.66	35.71%
Life-Long Learning	4.00	4.0	4	0.70	78.05%
Contribute to Human Health and Well-Being	4.14	4.0	4	0.61	88.10%
Training of Future Scientists	3.31	3.0	3	0.68	28.57%
Develop a Deep Sense of Wonder and Curiosity	4.19	4.0	4	0.71	83.33%
Pursue Progressively Higher Levels of Study	3.12	3.0	3	0.71	21.43%
Sustaining Earth's Systems	4.26	4.0	5	0.77	80.95%

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

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

As was described in Chapter 5, commentary from the expert panel indicated that many of these stated goals seem complementary to one another to the point of needing to be reorganised under more comprehensive categories. In particular, most recommendations of this type expressed a desire to take (2), (4), and (6) and organise these under a single goal which could be described as “sustainability practices”, “sustainability-oriented citizenship” or related terminologies.

Since the goals of science education traditionally inform what the stated outcomes may (or will) be in the traditional undertaking of curriculum development and should be a set of declarations about the ultimate purposes of the pursuit of science education, it is noteworthy that the expert panel has taken certain non-traditional positions as they forecasted outward. That is, in addition to what is of interest from consensus positions are areas of agreement about what has been *rejected* by the panel (what I have been referring too as negative consensus).

The expert panel has provided, from its quite stark negative consensus positions, some strong indicators that science education in Canada *does not* (or perhaps should not) desire to include among its primary goals:

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

The commentary rendered on these two goals was not entirely dismissive of these aspects as being unimportant, but rather that these should not be granted a level of emphasis such that other goals cannot be serviced adequately for the larger

proportion of students in science education. This is where the distinction should be noted. It is not so much that the professional science pipeline is not important to the members of the panel, but that it is not for the K-12 system to operationalise this aspect on behalf of science to the exclusion of all else. There were voices, however, expressing quite passionate views on whether or not the K-12 science education system has a responsibility for the training of future scientists. One such voice, and one who in the past has provided reviews of the impact on science education in Canada by virtue of the pan-Canadian Framework, had this to say:

“The idea of training the next generation of scientists is part of economic thinking—the former era of saying “we need scientists so let's start training them in our schools”. This is very wrong thinking and we have the post-Sputnik reforms to show us that this approach does NOT work anyway. What we need to do is re-focus towards an authentic, citizenship-based science (STSE) and fully realize this curriculum objective--over the disapproval and censure of university science faculties--and get school science education on track. Then we will find, I'm convinced, that more students will be interested in a science career. Of course, those students will be expecting a different, more relevant science education to these purposes at the university level--this is a good thing!!” (2087PE)

A similar view was held by a professional astronomer who added a caution about the need for both critical awareness of global trends and appropriate training:

“Future scientists -- those whose worldviews and motivations make science-related careers attractive - will do just fine in any science curriculum. Let the training of scientists blossom at the post-secondary level rather than commit 90% of the high school population to the goal of training scientists.

Citizenship in a national, technological society speaks to the relevancy required of science for students, and it will automatically transfer to the global context, hopefully with critical appraisals of globalization by market forces.”

(1091PI)

It is not only some obscure moral imperative with respect to the role science education in schools should or should not have in the training of future scientists. Certain panel members also identified an enduring practical problem which forces many district- or school-based decisions about the kind of science orientation is put in place. The following observation came through an interview with a science teacher educator who has filled a variety of employment roles in the Canadian context – science teacher, curriculum developer, and the public understanding of science:

“Science education has always had a dichotomy of goals: science for all (the Vision 2 of Roberts, and science for scientists (his Vision 1). Science courses based on science curricula tend to be implemented with science specialization in mind, in spite of some jurisdictions having courses for students who are not intending to specialize in the sciences like [my province].

Often, schools find it a challenge to offer these courses due to school size, numbers of students interested in taking them and so the science specialist courses are offered so as to not disadvantage those students who want to specialize in science in post-secondary. So we have a practical problem being solved by the wrong set of solutions. I believe that science curricula that focus

on citizenship and understanding our place and impact within Earth's natural systems is relevant for all students, regardless of whether or not they pursue traditional careers in the sciences.

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.” (2001TE)

Two other goals – science education for economic competitiveness and scientific career development – received low enough ratings to consider these as having marginal support. Over both Rounds 2 and 3, COHORT 2 held somewhat more favourable views as to the importance of science as preparation for being in the “science career pipeline” goals than did COHORT 1 (cf. Table 8 in Chapter 5). Taken together, a strong argument is presented for leaving the preparation of future Canadian scientists to the post-secondary institutions and other scientific agencies. So long as the foundations have been laid for advanced study in the K-12 formal education system, the same system could aspire to a very different set of priorities and goals.

Data Analysis of Delphi Round 1: Research Question RQ3

Seed 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?

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; the critical and visible role of the Council of Ministers of Education Canada (the CMEC)⁴². 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 context of any discussion about a national vision for science education in Canada. That is, the complexion of Canadian communities is undergoing rapid change. This raises

⁴² Pour plus de renseignements sur le Conseil des ministres de l'Éducation, Canada voir: <http://www.cmec.ca/fr/>; For more information on the Council of Ministers of Education, Canada see: <http://www.cmec.ca/>.

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. 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. One member of the expert panel, who is a geoscientist at a large western-Canadian institution, was able to illuminate some of the above considerations – particularly in relation to inter-provincial cooperation. Her perspectives help to illustrate the potentially unique nature of a Canadian perspective on science education:

“The current system favours innovation in science education because visionary ideas within one province can be implemented, and its success can guide other provinces towards that innovation. The innovators are not held back by the inertia of the status quo. The Pan- Canadian Science Framework is a case in point. The compromises and concessions made by reaching a federal consensus diluted some of the innovations which were tabled by several provinces. Another example is the necessary innovation of including Indigenous knowledge in school science. Some provinces have progressed to the point of having textbooks that support teachers in their inclusion of Indigenous knowledge; while the provinces that resisted innovations in the Pan-Canadian Framework are content with giving lip service to this and other innovations (i.e. tokenism, or nothing at all).” (1006PS)

The following is an excerpt from a lengthy interview conducted with a member of the panel, and illuminates a great many of the perspectives on the past (and present) functioning of the Canadian system of education with special reference to the development of curriculum frameworks. This is an individual who – for over 35 years - has at certain times been an “insider” working with a provincial ministry of education and at other times an “outsider” working among key stakeholder organizations. Note how this individual after having witnessed three large-scale science curriculum reform periods in Canada alters her view over time with respect to the need for a federal-level presence in education. As such, it is instructive to include her commentary:

“Initially in my career I held the view that Canada should have a federal department of education with responsibility for K to 12 education; however, since working with educators in different jurisdictions and in becoming more familiar with several education systems within Canada my view has changed. This is due to a better understanding of Canada as a federated country with a diversity of geographical challenges, regional origins and history. I am convinced that education from early years to Grade 12 should reflect and address the challenges inherent within the diversities of Canada’s different jurisdictions. I now view that jurisdictional responsibility for education is a strength and an opportunity – not an obstacle.” (From an interview with 2001TE, April 28, 2014)

Data Analysis of Delphi Rounds 2 and 3: Research Question RQ3 Part I

In Round 2, in addition to the rating scales which were to determine expert panel opinion on national and global trends, foundations, and goals for Canadian science education, a number of other items were designed to explore aspects of science education in Canada that stemmed from the many comments in Round 1. I had an interest in the degree to which former vision statements of national-level science education documents still held relevance (or did not) for today and looking forward in terms of forecasting a vision for the next generation. To do this, panel members were presented with past vision statements related to the purposes of science education in formal schooling – one from the Science Council of Canada report *Science for Every Student: Educating Canadians for Tomorrow's World* (SCC, 1984c) and the other from the *Common Framework of Science Learning Outcomes: the Pan-Canadian Protocol for Collaboration on School Curriculum* (CMEC, 1997). These vision statements were presented to the panel members as follows, but the questionnaire instrument intentionally did not indicate the source document (**boldface** here):

1984 Science Council of Canada Vision Statement: Imagine that the following description of the relevance of science education was written in the early 1980s:

"Tomorrow's citizens and decision-makers are in school today - are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future."

1997 Pan Canadian Science Framework Vision Statement: Imagine that the following description of the relevance of science education was written in the early to mid-1990s:

"Canadian society is experiencing rapid and fundamental economic, social, and cultural changes that affect the way we live. Canadians are also becoming aware of an increasing global interdependence and the need for a sustainable environment, economy, and society. The emergence of a highly competitive and integrated international economy, rapid technological innovation, and a growing knowledge base will continue to have a profound impact on our lives. Advancements in science and technology play an increasingly significant role in everyday life. Science education, therefore, will be a key element in developing new literacies and in building a strong future for Canada's young people."

The expert panel members then had an opportunity to indicate whether these statements were still relevant today, no longer relevant, or would be if these were changed. Figures 14 and 15 (next page) demonstrate how the expert panel – both cohorts combined – responded to the SCC and CMEC vision statements:

Figure 14: Responses of Expert Panel to the 1984 Science Council of Canada Vision Statement.

1984 Science Council of Canada Vision Statement







Response	Chart	Percentage
Yes, as is		59.0%
No, not relevant		2.6%
I would choose to modify it		38.5%

Figure 15: Responses of Expert Panel to the 1997 Council of Ministers of Education, Canada Vision Statement.

1997 Pan Canadian Science Framework Vision Statement

Response	Chart	Percentage
Yes, as is		77%
No, not relevant		0%
I would choose to modify it		23%

Significant numbers of panel members indicated that one or both of the visions still held relevancy for today, and verbatim. If the choice was made in the questionnaire to modify the item statement, panel members were required to comment as to what that modification would entail. There were 18 members who provided comments on this item. The requirement invited some interesting commentaries from among those who would have chosen to make modifications to the vision statements. Rather than re-writing the statement, most offered perspectives instead. One thread emerging in the revision comments was the incorporation of a sustainability focus which was not a possible consideration in the early 1980s but may well have been an oversight (missed opportunity?) in the

pan-Canadian Framework of the late 1990s. Here are three samples of how the visioning statements could be modified – one re-writes the statement in full, the remaining two are commentaries:

“Tomorrow's citizens and decision-makers are in school today - are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, with Earth systems that are dramatically in decline Canadian students need more, better and a different science education to prepare them for the future, and contribute to the emergence of a sustainable society that nurtures, and is in harmony with, our home planet. Canadians are becoming aware of an increasing global need for an integrated sustainable environment, economy, and society. Advancements in science, technology, innovation, economics and social conditions play increasingly significant roles in everyday life. Science education may well be a key component in developing the necessary new literacies for building a strong future for Canada's young people, and indeed a growing global population, but science alone will not be sufficient to re-create the essential harmony with a planet that society has progressively plundered for 10 millennia. Canadians must address an enormous challenge - solutions are achievable with sufficient will and skill.” (2067PD)

“Our increasing understanding of the physical world and technological capacity presents new opportunities and challenges. Science students of today need to be equipped to engage in an emerging discussion of values. Once, we were limited by what was possible. In the future we will be able to, and be required to, make choices about what is desirable. Increased complexity and a frenetic pace need not be inevitable outcomes.”

“I would need more time to think about how to rewrite these, but I can comment on why I would modify the statements. I find the phrase "more and better science education" from the 1980s vague. The statement does not provide a strong enough argument and seems more self-serving of science education. More along

the lines of science education looking within itself for solutions like Roberts' Vision 1 scientific literacy. In the statement from the 1990s a very significant missing thing for me in this statement is the omission of any reference to the political landscape. Not only is our society experiencing "rapid and fundamental economic, social, and cultural changes" but we are also experiencing fundamental political changes that affect the way we live."

We are living today at a time where virtually all school districts in Canada have crafted vision and mission statements. It is more than a curiosity to me that the very sets of statements which are intended to be broad in scope and liberating are just as frequently deemed delimiting by other observers. If there is a further attempt at a national-level vision for science education in Canada in future, it may not wish to begin with a vision statement.

Interpretation of the Data – Opportunities and Barriers to a National Vision for Canadian Science Education - Rounds 2 and 3

Research Question Addressed – RQ3

In both Round 1 and Round 2, the expert panel was requested to respond to a series of rating scales related to these aspects of Canadian science education policy that were connected to RQ3 – identifying and defining potential opportunities and barriers to the development of a national vision for science education. The questions took the form of a series of statements as follows and were rated on a 5-point Likert scale with 5 = agree strongly and 1 = strongly disagree:

- 1) The constitutional provisions in Canada for provincial governments to have control of education provides a favourable situation for science education in Canada.
- 2) The Council of Ministers of Education, Canada (the CMEC) should initiate work on a new Canadian vision for science education.
- 3) Deliberate and open consultations with the stakeholders is the most effective way of ensuring that future science education policy in Canada is relevant to the needs of society.
- 4) The Canadian provinces should collaborate with the international community on the development of a set of agreed-upon international standards for science education.

The results in response to this series of questions is presented in Table 11 below:

Table 11: Expert Panel Ratings to Policy-Making Positions in Science Education (COHORTS 1&2)

COMBINED CONSENSUS - COHORTS 1 & 2					
OPPORTUNITIES and BARRIERS to a CANADIAN VISION					
	COHORTS 1 & 2 (N = 42)				Consensus Level
	Mean	Median	Mode	S.D.	
Is the Federal System Favourable for Science Education?	3.07	3.0	3	1.25	48.78%
Should the CMEC Initiate New Science Education Policy?	4	4.0	4	1	78.57%
Are Open, Deliberate Consultations Needed for Future Science Education Policy Decisions?	4.27	4.0	4	0.81	87.80%
Should Canada Collaborate on New International Standards for Science Education?	2.98	3.0	3	1.01	31.71%

In terms of their views on the federal system of jurisdictional control over education systems, COHORT 2 (60.00%) was much more optimistic than COHORT 1 (38.10%) on the issue of whether the current system provides favourable conditions for the development of a national vision. In the written justifications, it was very clear that for many, the real manner in which things “get done” in education in Canada is at the provincial level. There was general favour for seeking national views and visions on science education so long as these did not diminish in any way the autonomy of the provinces. With a S.D. of ≥ 1.10 on this item, there is no clear consensus position. The distribution of responses is actually quite reflective of a situation with high levels of ambiguity. This is a type example of a dissensus position among panel members. Table 12 on the next page provides another representation of the results of this item (across both cohorts):







Table 12: Expert Panel Ratings – Canadian Education Systems – Favourable to a New Vision for Science Education (COHORTS 1&2).

Response	Chart	Percentage	Count
5-Agree Strongly (5)		14.3%	6
4-Agree (4)		23.8%	10
3-Neutral (3)		26.2%	11
2-Disagree (2)		21.4%	9
1-Disagree Strongly (1)		11.9%	5
NQ-Not Qualified (6)		2.4%	1
Total Responses			42
Mean			3.14
Median			3.00
Variance			1.74

Expert panel members were very favourable to the Council of Ministers of Education, Canada (CMEC) to initiate the construction of a new vision for science education in Canada. Commentary indicated that this process did not have to lead to an actual CMEC framework on science education (similar to the Pan-Canadian Framework of 1997), but was welcome from the standpoint of representing a symbol of unity of purpose that could then be translated into curriculum change among the jurisdictions. Given the somewhat high levels of dissatisfaction at the outcomes of the Pan-Canadian development 20 years ago (a CMEC-led project), providing such high levels of confidence to the CMEC to consider a new visioning initiative is notable. Moreover, with a consensus level of 85.71% among COHORT 1 contributing to the overall aggregate consensus at 78.57%, it seems evident that the newer generation of science educators and other stakeholders in the expert panel view a new CMEC vision as a priority position.






Table 13 provides a visual representation of the results of this item (across both cohorts):

Table 13: Expert Panel Ratings – Should the CMEC Initiate New Vision for Science Education? (COHORTS 1&2)

Response	Chart	Percentage	Count
5-Agree Strongly (5)		33.3%	14
4-Agree (4)		42.9%	18
3-Neutral (3)		11.9%	5
2-Disagree (2)		7.1%	3
1-Disagree Strongly (1)		2.4%	1
NQ-Not Qualified (6)		2.4%	1
Total Responses			42
Mean			4.05
Median			4.00
Variance			1.07

By virtue of the combined consensus position of 87.80% on the issue of conducting multi-stakeholder consultations as a natural step in the science curriculum policy-making sphere of activity, a sharp rebuke is being handed down regarding the *lack of a stakeholder processes* in the development of the 1997 CMEC Pan-Canadian Framework (Aikenhead, 2000). Alternatively, the expert panel is offering an affirmation of the deliberative inquiry conferences approach which was the hallmark of the Science Council of Canada study 30 years ago. Again, COHORT 1 and its opinions were the driver (at 95.24% consensus level) of this overall very favourable position on stakeholder inputs. Table 14 provides representation of the results of this item (across both cohorts):

Table 14: Expert Panel Ratings – Stakeholder Consultations in Science Education Policy-Making (COHORTS 1&2)

Response	Chart	Percentage	Count
5-Agree Strongly (5)		42.9%	18
4-Agree (4)		42.9%	18
3-Neutral (3)		7.1%	3
2-Disagree (2)		4.8%	2
1-Disagree Strongly (1)		0.0%	0
NQ-Not Qualified (6)		2.4%	1
Total Responses			42
Mean			4.31
Median			4.00
Variance			0.71

The views of the expert panel on whether the Canadian provinces should collaborate with international education partners on the establishment of a set of agreed-upon international standards for science education (De Boer, 2011; Waddington et al., 2007) provided little in the way of clarity on this issue. With just over 30% of the expert panel rating this as being moderately important (3) or important to do (4) and just as many expressing no opinion there is little in the way of support for a particular position. It would require further cross-correlative or matrix-driven analysis to determine if those who deemed this option as important had similarly favourable attitudes towards variables such as science-oriented skills development or were strongly supportive of the economic agenda in science education. International standards development remains an emergent, contested issue which warrants further national and inter-provincial collaboration and discussion of its implications. One panel member described the prospect of working towards international science standards from the point of view of an

experienced voice from COHORT 2 who wrote a position paper for the 1984 SCC study. It is a notable comment, particularly with respect to how the prospect of international standards was received internationally at the conference level:

“Such a process invites further colonization by the USA and some European nations. I have attended international conferences sponsored by UNESCO that had the explicit purpose of arriving at a globalized science curriculum. The conference organizers were always marginalized by the vast majority of nations that valued their own culture's approach, instead of America's so-called standards. STEM, for instance, is purely a slogan for the re-introduction of 1990's-era colonialization of the science curriculum.” (2021PE)

Other perspectives on international standards development – and a Canadian participatory role – was enlivened by some 39 comments from the panel. One theme regularly emerging was that the constitutional aspects of Canadian education systems were viewed as a serious impediment to our participation in any international collaboration around standards. Nevertheless, the panel was divided on this issue as the following comments attest:

“I support the notion of broad international perspectives being considered in the redevelopment of science curriculum, but I believe this might best be sought by an arms-length assembly at the federal level, and not provincial governments.”

“I believe it could be advantageous to collaborate with education officials from other countries that have already proven to have developed effective programs. I am not convinced that trying to achieve a set of agreed-upon international standards would prove to be an effective approach.”







“I believe that the opportunities for global education are incredible - I have a difficult time seeing how political regions can be the drivers for this model -- I see schools and communities taking the lead on engaging student and teacher leaning globally.”

“While I would support an ongoing educative engage with the international community on science education (its purposes, etc.), an engagement for the purpose of establishing agreed-upon international standards for science education would end up with such generic standards that they are (almost) useless for the Canadian provincial context. Cultural differences across the globe are simply too different.”

“Sounds like a bureaucratic boondoggle in the making to me!”

Table 15 provides an alternative representation of the results of this item across both cohorts. No particular position has been taken (or can be identified) by the expert panel with respect to international standards.

Table 15: Expert Panel Ratings – Collaboration by Canadian Provinces on International Science Education Standards Development (COHORTS

Response	Chart	Percentage	Count
5-Agree Strongly (5)		2.4%	1
4-Agree (4)		31.0%	13
3-Neutral (3)		35.7%	15
2-Disagree (2)		19.0%	8
1-Disagree Strongly (1)		9.5%	4
NQ-Not Qualified (6)		2.4%	1
Total Responses			42
Mean			3.05
Median			3.00
Variance			1.22

1&2).

The next and final item to which the expert panel responded was to consider variables related to characteristics of what could be called the “Canadian mosaic” – aspects which can include indigenous peoples’ voices in Canadian society, interprovincial co-operation in education, cultural and linguistic diversity, electoral cycles provincially/federally, the control of curriculum by provincial ministries of education, and the very physical landscape of the country. The rating scale in this instance used a *semantic differential* which – as described in Chapter 3 - is useful when there is a desire to rate possibly polar opposites on an issue. In this case, the ‘poles’ were “opportunity to” and “barrier to” the establishment of a common national vision for science education in Canada. Table 16 below provides the responses across both cohorts:

Table 16: Contributors to a National Vision for Science Education – Factors Unique to Canada.

COMBINED CONSENSUS - COHORTS 1 & 2					
THEME –CONTRIBUTORS to a NATIONAL VISION for SCIENCE EDUCATION in CANADA					
	COHORTS 1 & 2 (N = 42)				Consensus Level
	Mean	Median	Mode	S.D.	
Note: These ratings were on a semantic differential scale from +2 to -2.					
Voices of Indigenous Peoples	0.9	1.0	1	0.74	68.29%
Inter-Provincial Cooperation	0.63	1.0	1	1.13	70.73%
Cultural Diversity	0.75	1.0	1	0.74	65.85%
Linguistic Diversity	0.24	0.0	0	0.66	NEUTRAL
Provincial Electoral Cycles	-0.93	-1.0	-1	0.75	73.17%
Federal Electoral Cycles	-0.54	0.0	0	0.74	48.78%
Control of Curriculum by Provincial Ministries of Education	-0.17	0.0	-1	1.34	NEUTRAL
Physical Geography	0.18	0.0	0	0.71	NEUTRAL

In assessing these characteristics of the Canadian ‘landscape’ this was intended as more of an exploration into the “territories where curriculum may have its ‘*habitus*’ ” than a rigorous set of insights (Bourdieu, 1990; FarELL, 2010). Of the variables demonstrating near consensus positions (e.g., voices of Indigenous peoples) and those achieving consensus (i.e., inter-provincial cooperation (a distinct opportunity) and provincial electoral cycles (a distinct barrier)) it is important to recognise that the semantic interpretation of the rating scale was quite ill-defined among most respondents. The question seemed to provide more of a springboard to commentary than any hard positioning. In the instance of the Voices of Indigenous Peoples as a contributing factor (as opportunity) for achieving a national vision, the COHORT 1 consensus position (at 76.19%) was much more supportive of indigenous voices than COHORT 2 (at 60.00%). Taken together, there is some level of agreement that is notable, particularly since the role of indigenous perspectives particularly related to an *indigenous science* were not well supported even among members of the expert panel who are themselves treaty status.

There was significant levels of concern about the negative impact on visioning for education that derives from short-term electoral cycles at the provincial level coupled with the high status and high visibility systems of education have in the Provinces. As has been developed at length by Levin (2001; 2007; 2008) having access to, developing an appreciation for, and knowing how to navigate the political sphere in education (both the small ‘p’ and the large ‘P’ varieties) is a crucial opportunity to effect change at all levels in a sometimes

large, archaic, and monolithic system. Many on the expert panel – in both cohorts – were not sanguine about the political expedient in education that can overwhelm the best of intentions from the “outsider” groups. The development of the Pan-Canadian science framework has been described by one member of COHORT 2 as having been “a classic in regard to tight control over curriculum and purposefully and intentionally sidestepping the legitimate stakeholders and opting for an exclusively bureaucratic solution” in the manner of recent remarks about the “rise of bureaucratise” by Fensham (2012).

Data Analysis of Delphi Rounds 1, 2 and 3: Research Question RQ3 Part II

Seed 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.

Seed question 4 in the Delphi study intended to address the following component of research question RQ3: The definition and characterization of consensus on the distinguishing characteristics of science education unique to Canada and the roles, responsibilities, and relationships among the stakeholder community. More specifically, the expert panel groups were requested to identify who (or what) would be chiefly responsible for the development of science education policy at the provincial level as we move forward to 2030 and, might there be contributing variables to a “Canadian approach” to science education that positions Canada uniquely among the international community.

Interpretation of the Data –A Canadian Approach to Science Education? - Rounds 1, 2 and 3

Research Question Addressed – RQ3

Roles and Responsibilities in the Construction of Science Curriculum

There is perhaps no other issue that invites contested commentary in education 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 have a constitutional entitlement to an opinion. As one member of the panel put it with an admissible bias by virtue of being among science education faculty:

“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 are positioned to take the longer view. With the ever present battles between governments and teachers, I would put the civil servants and the teachers side-by-side under a neutral third party – that being the education faculties.” (2030TE)

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 (Bloch, 2014). In the Delphi Round 2, the expert panel provided opinion on roles and responsibilities across 10 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 variables:

- 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 15 other groups.

Table 17 provides the overall ratings across these 16 stakeholder groups:

Table 17: Roles and Responsibilities in Canadian Science Curriculum Development.

COMBINED CONSENSUS - COHORTS 1 & 2					
ROLES and RESPONSIBILITIES in SCIENCE CURRICULUM DEVELOPMENT	COHORTS 1 & 2 (N = 42)				
	Mean	Median	Mode	S.D.	Consensus Level
	Ministers of Education	3.43	3.0	3	1.17
Senior Staff in Provincial Ministries of Education	3.38	3.0	4	1.03	47.62%
Science Education Specialists in Ministries of Education	4.00	4.0	4	0.94	73.81%
Industry Professionals	3.45	3.5	4	0.86	50.00%
Faculties of Education (University)	4.19	4.0	5	0.77	78.57%
College Faculty	3.81	4.0	3	0.83	59.57%
Parents	2.69	3.0	3	1.00	19.05%
Students	3.05	3.0	3	0.91	33.33%
Science Teachers (K-12)	4.26	4.0	4	0.63	90.48%
Academic Scientists	3.64	4.0	3	0.82	52.38%
Aboriginal Elders and Knowledge Keepers	3.55	4.0	4	0.86	57.14%
Concerned Citizens (Conflict Free)	2.69	3.0	2	0.78	16.67%
Non-Academic Scientists	3.05	3.0	3	0.82	28.57%
Science Communicators (e.g. media, writers)	2.60	2.5	2	0.91	19.05%
Labour Organizations	2.19	2.0	3	0.99	9.52%
Provincial Roundtable for All Stakeholders	3.24	3.0	3	1.06	42.42%

As an aggregate panel, the results of the stakeholder group ratings provide evidence that there are just three identifiable groups who should be entrusted – at least in terms of significantly collaborative and decision-making roles – with science curriculum construction. These are: (1) science education specialists in Ministries of Education; (2) Faculties of Education, and; (3) K-12 Science Teachers. Each brings to the enterprise a set of biases, expertise, knowledge ability, societal status, and areas of focus. To some extent, these groups are representative respectively of (a) the enactment of the political will to have a vision for science education; (b) the pedagogical content knowledge that interprets the vision for the system, and; (c) those who are the “caregivers” to the students in fostering the many aspects of the received and learned curriculum.

Just as notable are professional positions and societal roles which were not granted the same status of final decision-making – particularly Aboriginal Elders and knowledge keepers, academic scientists, professional scientists not attached to academic institutions, industry professionals, and the community of colleges of applied arts and technologies. These stakeholders have been granted an advisory capacity which might be expected given the complexion of the panel which was rather skewed to these groups as in the minority. Few members of the panel directly filled positions among these groups at the time of the study. Alternatively, there may be the view that the distinction between science as practiced and science as school-based practices makes the curriculum development role of the scientist an anachronism to some (think of Trajectory 1 science in Chapter 2). The professional boundaries accorded stakeholders in curriculum, in my experience,

are somewhat permeable due to the variety of professional experiences and employment profiles which are afforded science educators in particular over their careers. Such distinctions allow for individuals to bring to curriculum policy-formation, curriculum implementation, teaching and learning environments, and a national study such as this certain strengths, experiences, and a potential for shared, multi-perspective wisdom (see quote on page 336).

The Importance of Objectives in the Canadian Science Curriculum

In the Science Council of Canada Study, an entire chapter of *Science education in Canadian schools: Volume 2; Statistical database for Canadian science education. Background Study 52* (Orpwood and Alam, 1984) was devoted to “objectives of science teaching” (their Chapter III). Though this study is not looking particularly at the substance of teachers, teaching, and learning in science there is one set of variables that holds interest in terms of identifying what it means to “study science in a Canadian school”. This set, also assessed by the Science Council research team, relates to teacher views on the relative importance of fourteen different ‘objectives’. That study differentiated these objectives across 3 levels of teaching science among those active in classrooms at the time of the study in 1981-1984 – early years, middle years, and secondary (senior) levels. In this study, I wanted to have a second look at these objectives, remove those that are no longer of significance today (e.g., science learning among female and male students as that gap has been closed tight in the last 20 years in Canada), and have the expert panel rate their significance. Before we look at those results, it is

helpful to see which “lenses” the members of the expert panel were viewing as they participated in the Delphi study. And so, prior to rating the objectives for science teaching, each respondent provided the following scaffolds: (1) whether or not they were actively teaching science or felt they had *never* been a teacher of science in any capacity; (2) what levels had most of their teaching taken place, and; (3) what their most significant ‘professional lens’ was. Figures 16 through 18 below provide for how the expert panel members positioned themselves on those indicators.

Figure 16: Teaching Level Profiles of Expert Panel Members Actively Teaching.

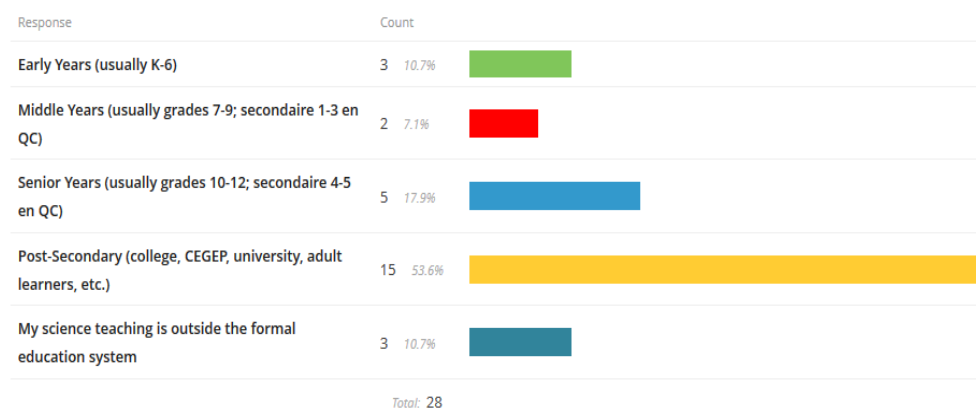


Figure 17: Teaching Level Profiles of Expert Panel Members Not Currently Teaching.

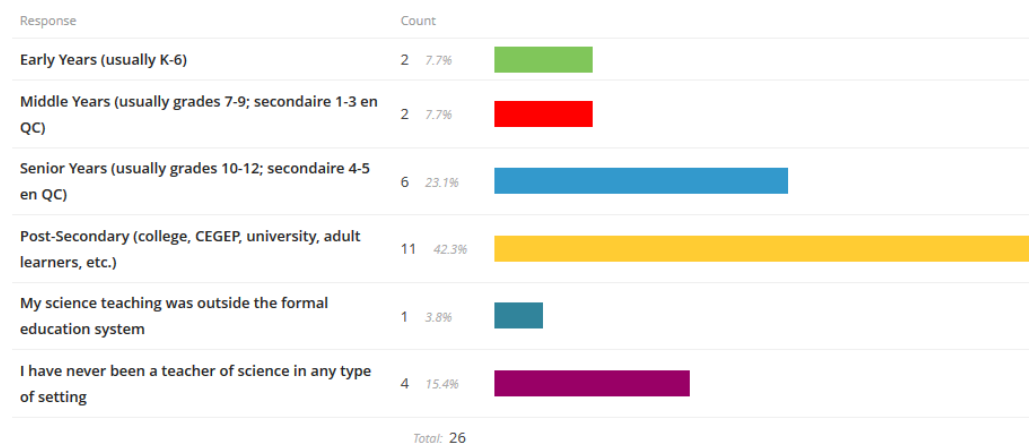
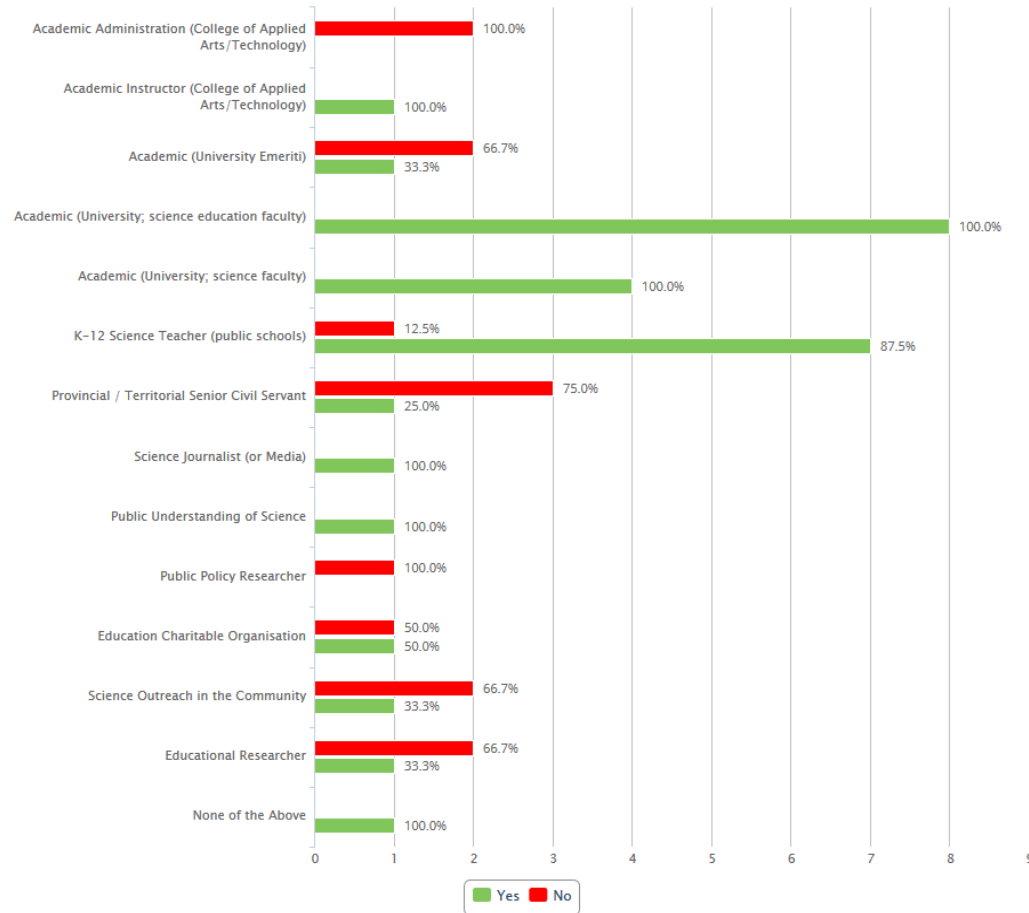


Figure 18: Most Significant Professional Lens of Expert Panel Members Teaching.

Note: Green indicates actively teaching science; Red indicates not currently teaching science at the time of the study.



Providing an indication of their most significant *professional lens* which had guided and informed their responses throughout the study was a suggestion of one of the expert panel members who had repeatedly felt interior conflict in the study by virtue of having had such wide-ranging experiences as a science educator. For those who had a great variety of professional profiles in science education, this was not entirely straightforward. Here is an anecdote from a brief

exchange conducted in-study with one member of COHORT 2 (from 2001TE, April 29, 2014):

“I have chosen the professional position of educational researcher since one choice is needed for this study’s questionnaire; however, I feel that it is somewhat misleading and confining in the sense that my positions in a university setting were also influenced by my years as a practitioner in the formal K-12 education sector. I consider these latter positions that I have had throughout my career such as teacher (varying grades), K-8 science consultant, K-12 science and technology coordinator, resource developer and curriculum developer as also an important influence on my views as a science educator, or perhaps more specifically as a science education educator.

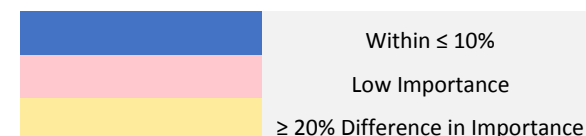
I cannot set aside the diverse experiences over the course of my career without acknowledging that each has shaped and built the perspectives that I hold today. These experiences culminated in conducting academic research recently about science curriculum policy. Although having conducted this research certainly was a strong influence on my responses, I chose educational researcher interpreting this to encompass life-long learning and being a reflective practitioner.” (2001TE)

Now that the ‘scaffolds’ have been set before us, we are in a position to look at how the 42 individuals who remained in Round 3 viewed a set of fourteen objectives for science education practice. There is hindsight from 30 years ago since these objectives were first rated by K-12 science teachers from among a sampling of hundreds of Canadian science teachers in the Science Council of Canada study. In this instance, the purposeful sample is not restricted to teachers of science but includes the panel members in this Delphi study. Therefore, caution

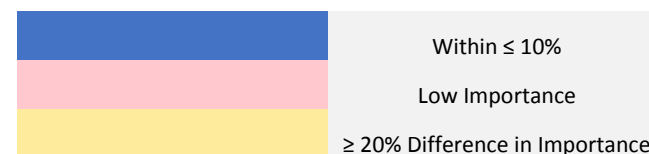
should be expressed that a much broader professional sample's results cannot be directly correlated with that earlier study. Nevertheless, I was confident that certain relevant opinions would come from rating these objectives a generation later. Here is what they have viewed as "important" to "very important" as components of a comprehensive science education in Canada (Table 18 below):

Table 18: The Relative Importance of the Core Objectives of a Canadian Science Education – in 1984 and Today.

COMBINED CONSENSUS - COHORTS 1 & 2						
IMPORTANCE of OBJECTIVES in SCIENCE (this study as compared to 1984 SCC study)	(THIS STUDY)				Consensus Level	Consensus Level
	COHORTS	1 & 2	(N = 42)		(THIS STUDY)	(SCC STUDY 1984)
	Mean	Median	Mode	S.D.	(Very important or essential)	(fairly or very important)
Understanding scientific facts, concepts, theories, laws, etc.	3.82	3.0	4	0.82	61.5%	96.1%
Developing personal/social skills (e.g., cooperation, communication, responsibility)	4.08	4.0	4	0.87	83.3%	86.1%
Relating the learning of science directly to career opportunities	3.36	3.0	3	0.90	38.5%	77.3%
Developing the necessary skills (e.g., numeracy, literacy) to understand science-related reading material	4.28	4.0	5	0.83	87.2%	89.2%
Understanding the nature of, and processes involved in, engineering or technology activity	3.62	4.0	4	0.88	61.5%	58.9%
Fostering attitudes usually associated with the scientific endeavor (e.g., curiosity, creativity, perseverance, skepticism, argument from evidence)	4.41	5.0	5	0.72	88.9%	95.7%
Appreciating the role of history and philosophy of science informing practice	3.28	3.0	4	0.89	46.2%	54.6%



IMPORTANCE of OBJECTIVES in SCIENCE (this study as compared to 1984 SCC study)	(THIS STUDY) COHORTS 1 & 2 (N = 42)				Consensus Level (THIS STUDY)	Consensus Level (SCC STUDY 1984)
	Mean	Median	Mode	S.D.	(Very important or essential)	(fairly or very important)
Understanding the practical applications of science	3.95	4.0	4	0.79	71.8%	92.2%
Developing the skills and processes of investigation (e.g., observing, classifying, conducting an inquiry, asking testable questions)	4.28	5.0	5	0.86	71.8%	90.2%
Understanding the relevance of science for students who are not aligned with Euro-centric traditions	3.21	3.0	4	1	43.6%	(Not Assessed in the SCC Study)
Relating scientific explanations to students' personal conceptions of the world	4.1	4.0	4	0.91	79.5%	86.9%
Understanding the way in which scientific knowledge is generated	4.31	4.0	5	0.73	84.6%	78.0%
Developing an awareness of the practices of science in Canada	3.36	4.0	4	1.04	51.3%	58.6%
Understanding the role and significance of science in the world of the 21st century	4.13	4.0	4	0.83	83.3%	87.9%



As stated, these two sets of data cannot be rigorously compared by virtue of differences in the substance of the two studies, different sampling rigour, and entirely dissimilar numbers of participants. It is illustrative, however, in a general way that not too much seems to have changed with respect to the objectives of a general science education in a Canadian setting. The “wisdom of the crowd” in the Science Council of Canada study thirty years ago has echoed down through the years. Many of the core objectives given high importance by teachers of science 30 years ago are also aligned with the priorities of those teaching science across a multitude of learning environments and from the multiple perspectives of the professional lenses of the expert panel. This study’s data on objectives indicates that the following have maintained their importance (or are, perhaps, trans-historical in nature):

- Developing personal/social skills (e.g., cooperation, communication, responsibility);
- Developing the necessary skills (e.g., numeracy, literacy) to understand science-related reading material;
- Fostering attitudes usually associated with the scientific endeavor (e.g., curiosity, creativity, perseverance, skepticism, argument from evidence);
- Relating scientific explanations to students' personal conceptions of the world;
- Understanding the way in which scientific knowledge is generated;
- Understanding the way in which scientific knowledge is generated.

There are other objectives that – though they have grown in relative importance in recent movements in science education and in academic discourse (STEM and

historical perspectives come to mind), they have yet to reach a level of significance that is accorded them by their chief advocates. These objectives include:

- Understanding the nature of, and processes involved in, engineering or technology activity;
- Appreciating the role of history and philosophy of science informing teacher practice and learning science;
- Developing an awareness of the practices of science in Canada, and;
- Understanding the relevance of science for students who are not aligned with Euro-centric traditions (which has, for the most part, replaced what was an emphasis on gender issues in science teaching and learning in the SCC study.)

Three other objectives, however, do constitute a departure from a unitary voice and warrant further attention with future studies. These include:

- Understanding scientific facts, concepts, theories, laws, etc.;
- Relating the learning of science directly to career opportunities, and;
- Understanding the practical applications of science.

Though this study focuses on forecasting a science education environment in Canada that “could be”, history is an eloquent teacher for having us appreciate the stubbornness with which science education holds onto its traditional objectives and frequently saying “this is how it has always been, and our success speaks on its behalf”. In a similar way to the background papers of the Science Council of Canada study, the expert panel is presenting a persuasive set of new

alternatives in science education – some implicit and others quite explicit. Until and unless the science teachers themselves are materially convinced that what they deemed important 30 years ago is being called into question yet again (and even then the objectives identified were not considered progressive enough), change will be slow to occur. One of the strongest threads of opinion coming from the expert panel is that the science education of 2030 might not even be imaginable today in the face of the accelerating rates of social, political, and technological change. It is worrisome for some observers on the panel that, in 2014, the Delphi panel as a group shows no inclination to place emphasis on career-building, legitimate scientific knowledge, the practical applications of science, and an awareness of the scientific practices occurring in Canada. In the 1970's, the Symons' Commission Report (cf. Chapter 2) had sent a strong message to all levels of the educational enterprise that it was important for Canadian students to “know themselves” in order to know their place in an increasingly networked world. In the SCC study, we read that “....[the] critics may be right, but the teaching profession has not yet been persuaded. There is little doubt that what teachers believe to be important is a major influence – perhaps *the* major influence – on what actually takes place in classrooms” (Orpwood & Alam, 1984; p. 84). In the ensuing summary chapter, I will bring together the 54 original voices of the Delphi expert panel, with all the dialogue that has been presented here, to provide a new and defensible basis to begin a national deliberation openly on the question: “What should be the priority emphases in science education in Canada going forward?”

Chapter 7: Summary, Discussion, and Recommendations

This chapter will provide a summary of the research results of the three rounds of the Delphi study, some discussion as to their significance for Canadian science education, and provide recommendations for further research efforts and practical outcomes that could be implemented in the Canadian systems of science education. These components will be organized around the research questions.

Summary of Findings by Research Questions

The central purpose of this dissertation study was to identify the system conditions and principal theoretical foundations to develop a Canadian consensus on science education in the post-Pan Canadian Framework period through 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 the 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 an in-depth, anonymous, consensus-oriented and asynchronous process of inquiry. The inquiry - a modified policy Delphi approach – was conducted among an assembled community of science

and science education specialists from many locations in Canada. The following primary research question (PRQ) and its ancillary questions guided the research. Therefore, this structure has the PRQ responded to through the three ancillary research questions. What follows is a systematic summary of the research findings in accordance with these three questions.

Primary Research Question (PRQ):

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 the post-Pan Canadian Framework period?

Ancillary Research Questions (RQx):

1. What trends and conditions – both domestic and international – will serve to initiate and have defining influence upon future science curriculum change in Canada? (RQ1)
2. What characterises consensus (or 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? (RQ2)
3. What characterises 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? (RQ3)

Research Question RQ1

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

Research Question RQ1 Results

Round 1 of the Delphi involved the expert panel (N = 51) in responding to RQ1 through a seed question having similar wording. Following a four-week period in which participants submitted free-form, anecdotal responses I coded the text using qualitative research methods generally accepted in the field. This coding procedure provided 1,323 separately coded items in response. Frequency analyses using NVivo™ CAQDAS permitted a re-organisation of the coding to generate themes from the textual data. These themes constituted the ‘domestic and international trends’ as forecasted by the expert panel and thought to be those which would have significant – and possibly defining – influences upon science education in Canada to 2030. In total, eleven themes emerged from the data as thematic cluster groupings, all related to global trends. These themes were:

1. Science, Technology, Engineering & Mathematics (STEM)
2. Integration of Indigenous Perspectives / Knowledge
3. Developing Skills for the 21st Century
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

Detailed summaries of the nature and characteristics of these global trends themes were discussed in Chapter 5. What is re-presented here in the findings are those themes which surfaced from expert panel opinion as being significant.

The representative themes related to RQ1 were subjected to a variation on *impact factor* analysis which is a method that determines items perceived by respondents as being of most importance (Juniper et al., 1997). In total, six global trends were identified by virtue of the preponderance of responses that emerged from the impact factor analyses. There is deeper discussion of trends thought to affect and be impactors on science education in Canada in Chapter 6, but I will identify them again here:

- Globalisation influences and Neo-Liberal Economics (at 29.97%)⁴³
- Skills for the 21st Century (at 13.41%)
- Science Education and Sustainability (at 11.40%)
- Emergence of New Technologies for Learning (at 10.94%)
- The Relevance of Science Education for Students (at 10.32%), and
- Science, Technology, Engineering and Mathematics (STEM) (at 7.40%)

In Rounds 2 and 3 of the Delphi, the expert panel responded to a series of questionnaire items comprised principally of rating scales that requested they provide two types of opinion on the national and international trends which had emerged: (1) which of these did they *expect* would have some degree of influence,

⁴³ The percentages indicate the number of references in the coding as a proportion of all references in the question responses. For example, 29.97% implies that almost 30% of all responses to Question #1 included references to ideas, concepts, realities, etc. that could be applied to “globalisation”.

and; (2) which of these would they *prefer* to have some degree of influence in an “ideal” situation with regard for their personal and professional views on the future of science education in Canada. Stability was achieved in the vast majority of cases from Round 2 to Round 3. In this study, ‘stability’ was operationally defined as no more than one rating level of movement in a participant’s response to an item from Round 2 to Round 3. This definition of stability is consistent with that used in the Delphi study conducted by Collins et al. (2001). In terms of operationally defining consensus positions, a minimum of 70.00% of individuals in a cohort rating an item at ≥ 4.0 on a 5.0 scale was required. Given the nature of Delphi, rating scales, changing attitudinal environments, and individual judgement it was deemed appropriate to set the standard deviation level at ≤ 0.75 to assist in defining consensus positions. What has been outlined above will be consistent across all results reported here.

From the analysis provided by expert panel ratings, these were the global trends that were rated as being among those with the highest potential at being influential on science education going forward: Developing 21st Century Skills and Science and Education for Sustainability. The Integration of Indigenous Perspectives & Knowledge into Canadian science education trend held *negative consensus* meaning that the panel collectively perceived that it was not likely to become of significance if the systems are left to self-organise.

In terms of *desired* influences, the expert panel added to the list just mentioned by supporting the inclusion of the relevance of science education for students and a request to re-conceptualize the purposes of science education in

Canada. Moreover, only one-fifth of both cohorts were convinced that National and International Standardized Assessments should have *any role* in influencing the nature of Canadian science education. Given the present world-wide attention to such assessments (particularly by UNESCO and OECD internationally and the CMEC nationally), this is a finding of significance that needs to be followed in the field in the coming decades.

Research Question RQ2

What characterises consensus (or 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?

Research Question RQ2 Results

Impact factor analysis related to the Foundations of the Canadian science education system provided seven principal themes which could then be interpreted as providing the bases upon which curriculum, teaching, and learning in science would rest. Free-form Question #2 in the Round 1 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 of science education in Canada. The largest proportions in terms

of textual references based on reflexive and iterative coding have provided the following results in the category of “Foundations for Science Education”:⁴⁴

- Science, Technology, Society and the Environment (STSE) (at 34.56%)
- Science Education for Sustainability (at 17.45%)
- Scientific Knowledge (at 9.42%)
- Science Education for Global Citizenship (at 6.10%)
- Scientific Skills for the 21st Century (at 5.75%)
- Interacting Systems and Systems Thinking (at 4.01%)
- The Nature of Science (at 4.01 %)

When assessing these foundations for Canadian science education, both the Round 2 and Round 3 questionnaires afforded the expert panel with this guiding assumption on what was to be interpreted as a ‘foundation’: *“For the purposes of this study, ‘foundations’ refers to the large-scale aspects of a general science education that usually help to create frameworks from which science curriculums (curricula) are developed in the Canadian provinces. Alternatively, these foundations could be thought of as the explicit “bases” upon which science education rests and speaks to its various emphases.”*

From the analysis provided by expert panel ratings, these were the foundations of science education that were rated as being among those most defining of the curriculum to 2030: Science Education for Sustainability, Science,

⁴⁴ The percentages indicate the number of references in the coding as a proportion of all references in the question responses. For example, 34.56% implies that almost 35% of all responses to Question #2 included references to ideas, concepts, realities, etc. that could be considered appropriate to foundations or goals in science education.

Technology, Society and the Environment (STSE), Scientific Oriented Skills, the Nature of Science, and Scientific Knowledge. In Round 2, “science education for sustainability” had not yet emerged as a consensus category but was differentiated over a number of related themes that were first identified from the codings in Round 1. Those related themes were: Science Education for Global Citizenship and Interacting Natural and Human Systems. In Round 3, these subordinate, sustainability-oriented foundation themes became a single entity. There were no foundation areas that were rejected by the expert panel. This is an area where strong traditions for what is considered ‘foundational’ to the enterprise of science education in Canada and elsewhere exist. In addition, the two previous influences in curriculum – these being the Science Council of Canada study and the Pan-Canadian Framework – recognised four of these five areas in their recommendations. This study now reports that a fifth foundation – Science Education for Sustainability – has now emerged for consideration, discussions, and a definition.

The questionnaires from Rounds 2 and 3 in the study requested that the expert panel provide input and opinions on the following “Goals for Science Education” in Canada which had emerged from the coding of Round 1 contributions and impact factor analyses:

- Literacy in Science-Related Issues (at 51.61%)
- Develop a Deep Sense of Wonder and Curiosity (at 19.35%)
- Personal Character Development (at 19.35%)
- Democratic Citizenship in a Global Technological Society (at 18.55%)

- Sustaining Earth's Systems (at 18.55%)
- Career-building for a Technological Society (at 11.29%)
- Economic Competitiveness (at 8.06%)
- Life-Long Learning (at 8.06%)
- Training of Future Scientists (at 7.25%)
- Pursue Progressively Higher Levels of Study (at 7.25%)
- Contribute to Human Health and Well-Being (at 5.64%)

In order to provide an assessment of the eleven themes which emerged as related to the Goals of Science Education following impact factor analysis, the expert panel members participating in the Round 2 (N = 44) and Round 3 (N= 42) questionnaires were provided this guiding assumption defining a ‘goal’: *“For the purposes of this study, 'goals' refers to the larger-scale desired outcomes of a general science education that usually define the overall purposes of conducting science education in the Canadian provinces. In this instance, the goals are confined to what could define the K-12 system of science education; these goals are intended to serve all avenues of adult life.”* Therefore, in assessing the importance for their inclusion in Canadian science education, the goals constitute the “end-rationale” of the enterprise of science education more generally and K-12 (formal) science education in particular. The goals, consequently, should assist any Canadian in answering the fundamental question, “What is the purpose (or purposes) of science education in Canadian schools?”

Since the goals ultimately inform what the stated outcomes may (or will) be in the current (traditional) undertaking of curriculum development and should be a set of declarations about the ultimate purposes of the pursuit of science

education, it was noted that the expert panel has taken certain non-traditional positions as they forecasted outward. Consensus positions emerged in six areas following expert panel input into providing definition to the goals for science education. This list of goals is in descending order of importance to science education: Literacy in Science Related Issues (100.00% consensus level), Contribute to Human Health and Well-Being, Develop a Deep Sense of Wonder and Curiosity, Sustaining Earth's Systems, Life-Long Learning, and Citizenship in a Globalised Technological Society.

The expert panel recommended a marginal rejection ($\approx 35.00\%$ consensus level) of the following as goals for science education: Personal Character Development and Economic Competitiveness. Outright rejection ($\leq 30.00\%$ consensus level) occurred for these goals: the Training of Future Scientists and Pursuing Progressively Higher Levels of Study.

Research Question RQ3

What characterises 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?

Research Question RQ3 Results

Any study that engages expert opinion on forecasting the next generation state of science education will gaze at the regional landscapes which are shaped by educational control among the provinces and territories, but will also enlarge

that view to consider how a region contributes to national scope concerns. This study is no different in this regard. Discussions about the future of science education, as re-enforced here and echoed in the Science Council of Canada study 30 years ago, have to occur with simultaneity thirteen times – in the three territories and the ten provinces. Whether it is trends, foundations, goals, objectives, teacher education, assessment, students’ outcomes or any other considerations with respect to education, the multiple perspectives of the Canadian mosaic are shaped and re-shaped – thirteen times.

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 at various times passionate, polarized, unitary, respectful, or enraging. Participants have identified an array of contexts that are considered to be of influence in defining the future landscape of Canadian science education, 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; the critical and visible role of the Council of Ministers of Education Canada (the CMEC) and its support of the UNESCO and OECD agendas on assessment⁴⁵. The greater mobility of the Canadian population, alongside regional adjustments to demographics due to the dynamic of immigration factors, was viewed by the panel as contributors to the

⁴⁵ Pour plus de renseignements sur le Conseil des ministres de l'Éducation, Canada voir: <http://www.cmec.ca/fr/>; For more information on the Council of Ministers of Education, Canada see: <http://www.cmec.ca/>.

contexts of any discussions about a national vision for science education in Canada. That is, the complexion of Canadian communities is undergoing rapid change. Indeed, most would accept that the world has changed in the last 30 years, and education had better consider a response.

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. 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.

In all three Delphi rounds, the expert panel was requested to respond to a series of rating scales related to aspects of Canadian science education policy that were connected to the identification of, and the definition of, potential opportunities and barriers to the development of a national vision for science education here in Canada. The questioning put to the expert panel related to a Canadian vision for science education took account of the following perspectives:

- 1) The constitutional provisions in Canada for provincial governments to have control of education provides a favourable situation for science education in Canada.
- 2) The role of the Council of Ministers of Education, Canada (the CMEC) and whether it should initiate work on a new Canadian vision for science education.
- 3) The desire for and manner in which deliberate and open consultations with the stakeholders is an effective way (or ineffectual) in ensuring

that future science education policy in Canada is relevant to the actual perceived needs of the society.

- 4) The degree to which the Canadian provinces should collaborate among themselves in matters of science education and with the international community (e.g., on the development of a set of international standards for science education).
- 5) Contributors to, and barriers against, moving forward on a national vision when consideration is given to: the voices of indigenous peoples, inter-jurisdictional cooperation, cultural and linguistic diversity, federal/provincial electoral cycles, the mandate for control of curriculum among the ministries of education, and the circumpolar character of the country and its varied lands, ecologies and traditions.
- 6) The roles and responsibilities of the various stakeholder groups in Canadian science education – the “insiders” who have public accountability in education and the “outsiders” who can be influential in the processes of education but do not explicitly hold public accountability.
- 7) The multiple perspectives on the core objectives that should shape a general science education in Canada.

Chapters 5 and 6 provide appropriate levels of treatment of the research questions with respect to the above, and so here I will highlight a few notable consensus positions of interest in relation to RQ3. Expectedly, opinions were mixed on the question of Canada’s federal system of independent education systems and the degree to which this mutual independence (and in many cases of curriculum, inter-dependency) provides a favourable climate for a new vision for science education. Indeed the distribution of responses to Round 1 commentary in the Rounds 2 and 3 ratings provides as natural a range of opinion on the matter as could be expected. The high levels of variance on the ratings provides further

support to the difficulty of interpreting what was implied *by a favourable situation for science education in Canada*.

On the question of “should the Council of Ministers of Education, Canada initiate work on a new Canadian vision for science education?” there was a significant consensus (> 75.00%) that this is perhaps *the* organization in the country that has both the mandate to create a climate of change for science education among Canadian jurisdictions and the authority to initiate a new round of national-level discussions. For some involved in the study, such a process should get underway very soon.

The expert panel – by their own admission representative of fourteen distinct professional and educational affiliations – believes very strongly that open, deliberative, honest and face-to-face consultations are indispensable to the process of change in science education. The model that is most consistent with this view is that of *deliberative inquiry* (Orpwood, 1981).

When considering the future role of international standards, here again there were sharp divisions and a lack of consensus on how to proceed. COHORT 1, which is the chronologically younger age cohort, is more favourable to the notion of standards-setting than are their more experienced colleagues. This may be an instance of “two cultures” – one which operated in a time when matters of curriculum were more open to teacher professional discretion and the other which is accustomed to current emphases on assessment mass-scale, accountability measures in education, and a pervasive culture of test-taking.

With respect to contributors to, and barriers against, moving forward on a national vision with consideration given to the voices of indigenous peoples, inter-jurisdictional cooperation, cultural and linguistic diversity, federal/provincial electoral cycles, the mandate for control of curriculum among the ministries of education, and the circumpolar character of the country, members of the expert panel held favourable consensus positions (about two-thirds majority) on the role of Indigenous peoples' as important contributors to any national vision for science education and this was reflective of similar views on the character of Canada in terms of its open commitments to diversity, a pluralistic society, and multicultural milieu. An even stronger consensus emerged on the importance of inter-provincial cooperation in achieving a new vision. The tight electoral cycles of the provinces was viewed as an important, if not defining, barrier to looking longer-term at the vision for science education. Some members of the panel claim that this alone is a compelling reason to take the final decision-making on educational policy out of the hands of the provincial ministries and place it in the hands of third-party arbiters who will work collaboratively with the political and educational spheres of influence. One example of this is a view which provides new and important status to Canada's faculties of education in the curriculum development process.

Which brings us to the recommended roles and responsibilities envisioned for the science curriculum development process. In most Canadian jurisdictions, K-12 teachers are seconded from the field for a period of time to sit on development teams comprised of science specialists from provincial ministries of education with adjunct participation by other stakeholders. On occasion, those in

the ministries are *de facto* secondees. In times of fiscal restraint, it is not uncommon for the curriculum development process to be suspended altogether in favour of “adapting” curricula from other jurisdictions. Commentary from certain of the expert panel on this issue demonstrated that it can be both a threat and an opportunity to do this. What was thought ‘threatened’ was provincial autonomy combined with the importation of curricular architecture that had been developed in another place, for another time, and for another set of circumstances. That is, curriculum is adopted in a place for which it was never intended. The ‘opportunity’ rests with the value of sharing compelling new ideas, successful strategies, and trans-jurisdictional pedagogies which demonstrate potential or actual orientations to being successful.

Finally, in terms of the overall objectives of science education in Canadian schools, this study did not look explicitly at the substance of teachers, teaching, and learning in science. This was last accomplished with the 1984 SCC study. There are, however, a set of variables emerged in the present study which should hold our interest in terms of identifying what it will mean to engage in science education in a formal (or informal) Canadian setting as we go forward. This set of core objectives, which had also been assessed by the Science Council research team 30 years ago, related to teachers’ views on the relative importance of fourteen different ‘objectives’. That study differentiated these objectives across 3 levels of teaching science among those active in classrooms at the time of the study in 1981-1984 – early years, middle years, and secondary (senior) levels. In this study, since K-12 teachers was a sub-domain of a much more varied expert

panel heavily weighted with individuals from science education academia and other post-secondary level professional, I wanted the Delphi study panel re-rate these objectives. I removed those that were no longer particularly relevant today (e.g., science achievement among female and male students), and we had a second look at these under a very different demographic. There was surprising similarity in what was still expected as outcomes in Canadian science education (see results at the close of Chapter 6) with the notable exceptions of: (a) relating science learning to career opportunities (the majority of the expert panel viewed this option as servicing globalising economic forces) whereas 30 years ago it may have been viewed as more benign, and; (b) the role of scientific knowledge (e.g., factual material, scientific concepts, models, laws, theoretical positions in science, etc.). In sum, the orientation to science education to 2030 coming from this study and its participants can be summarised as including: the development of the skills and attitudes consistent with cooperation, personal and social responsibility; developing the requisite numeracy and literacy skills in order to understand the scientific issues of the day and just how influential science is in our times; balancing students' conceptions of their world with the ability to "inhabit" the ecologies of science and; recognising the critical nature of Earth's interconnected systems upon which we all depend in order for science to continue to occur at all as a human activity for generations to come, and; attitudes and a vision that includes attributes of intense curiosity, creativity, perseverance, healthy skepticism, and creating instances where arguing effectively from an evidential perspective becomes a commonplace.

Discussion and Recommendations

The research questions which guided this study were viewed, from the outset, as amenable to the assembly of a form of expert community intervention and response. There have been few such opportunities historically in Canada that would gather together a diverse, multi-perspective group of individuals who constitute important voices for, about and at times against science education in its current state of play. This study sought to reconcile the challenges of geographic dispersion, expertise, and professional ego in a unique effort to engage in forecasting about Canadian science education in an honest and open framework. It requires tremendous resources to convene iterative instances of deliberative inquiry among stakeholder groups. The modified policy Delphi methodology used in the organisation of this study provided the means, the structure, and the theoretical framework that has made the study possible and manageable. The expert panel, by the end of all three rounds of the Delphi, comprised 42 highly committed individuals of considerable abilities who participated in the first online only, anonymous, asynchronous, substantive discussions about science education that have occurred nationally to date. It has been thirty years since the last time such a diverse array of expert opinion was brought to bear on the many important questions that are arising in our times. The worth and depth of thought in their contributions were exceeded only by the sheer volume of response, their sense of the importance of what they were accomplishing, and by my admiration for them.

A criticism could be raised, and this was clearly identified in the research plan's cautions described in the opening chapter, that a Delphi study of this type

provides merely a moment in time among select individuals. This may appear to the un-appreciating eye as being too highly-selective and insular a process and one which has simply seized an opportunity. If this were the case, then seizure of the moment would come at some sacrifice to authentic results. I would argue that by virtue of the two-cohort design in this study, there are many moments in time and professional experience which were then assembled to provide the expert panel four months of contributions. The FluidSurveys™ online platform allowed for real-time monitoring across the entire expert panel at the researcher's discretion. There are instances where members of the expert panel cohorts spent more than twelve hours of their time to respond to one round of the questionnaire instrument. This attention simply could not occur in a real time face-to-face environment. I am convinced that the selection processes developed for this Delphi have been accomplished with careful attention to the literature on Delphi and the cautionary tales therein. One could make the claim that seminal conferences related to science education are *all* 'moments in time' (e.g., the Woods Hole, MA conference held in 1962 under the direction of Jerome Bruner; the deliberative conferences held 12 times over a three-month period in 1981-82 as the Science Council of Canada conducted its efforts at expert opinion). On occasion, a 'moment' in the history of education has become the first day of a paradigmatic shift in emphases.

This modified Delphi began from invitations sent to $N = 130$ individuals, $N = 54$ of whom were able to commit to Round 1. The rate of acceptance (41.53%) far exceeded the most optimistic expectations as the study was under

design. Attrition in subsequent rounds was at acceptable levels for the methodology, with N = 51 participating in Round 2 (94.44%) and N = 46 provided access to the panel deliberations in Round 3 (a 91.30% completion rate). Taking into account the 12 members who at various times found it necessary to leave the study and withdraw their data, the group dynamic was still very much intact and the array of professional affiliations remained quite consistent across all three rounds. The largest attrition rates were among active teachers and senior administrators whose schedules placed constraints on their ability to commit to the full 14 weeks of the study's expert panel activity.

Methodological Contributions

This study has provided the science education research community in Canada with important modifications to the classical Delphi methodology approach from a mixed-methods perspective. The original purposeful sample was derived from custom criteria and all contact information which was assembled for the database of invitations to the study was from open-sourced, online sources. This is only the second Delphi study in science education known to the researcher which used CAQDAS, and the first in the form of QSR NVivo™ 10.0 . The collaborations of Collins et al. (2001) and Osborne et al., (2003) is the only other study which made use of CAQDAS for coding of responses with QSR NUDIST 7.0. With a high impact factor in the literature and a citation number ≥ 450 with the Osborne et al., study, the research presented here can be considered to rest on firm methodological supports as a Delphi inquiry.

Additionally, this study sought to ameliorate many of the common criticisms of the use of the Delphi technique. Particular priority was given here to the following: 1) paying closer attention to the development of more explicit and stricter criteria for participant selection (the arbitrariness problem); 2) the provision of high volumes of information between rounds for participants' review (including the distribution of group responses for each item in response; 3) including accountability measures such as justification statements from each participant for each item rated (the expertise in opinion / accountability problem), and; 4) encouraging very low attrition rates between rounds through regular communications with participants (the overestimated level of consensus problem). Each of the solutions to common criticisms just noted align well with a broader set of recommendations for Delphi techniques which have been described by Sinha, Smyth & Williamson (2011). Their meta-analysis of 656 clinical medicine studies using the Delphi technique, further distilled to a detailed critique of a 15-study sample therein, provided for reporting quality across three aspects: size and composition of the expert panel; methodology used in the Delphi, and; reporting of results to the participants in detail. This study can now provide a model which can become the basis for further Delphi techniques to be designed for the purposes of examining expert opinion in matters relating to national-level education initiatives.

There is yet another set of perspectives of interest in the design and execution of this study. I had a desire to have it take on the characteristics of the “interrupted storyline” such that the Delphi shared in common the narrative

inquiry form of investigation advocated by Metz et al. (2007) and consideration for creating a “real-time” science story in the manner of Klassen (2009) and Clough (2011). In their view, student investigations have four parts: (1) context; (2) experimental design; (3) analysis and interpretation of the results, and; and explanation. In this study, these four phases are identified with: (1) the Canadian context in science education; (2) design of a modified Delphi methodology to inquire into the issues raised by the context of inquiry; (3) mixed methods approaches to data collection and the use of coding techniques, rating scales, and descriptive statistics, and; (4) an explanation of the results (in context) and looking ahead at next, practical steps. The story here was periodically “interrupted” by me after each Delphi round, the expert panel was held in abeyance, and they were provided an opportunity to assess each’s contributions iteratively.

Implications of the Research

The free-form contributions of the expert panel to the four ‘seed questions’ and the subsequent analysis of their ratings of the emergent themes raises important questions and considerations for science education in Canada. Many of these considerations will require firmer consensus on definitions before further steps can be taken towards action-oriented research and development of what has emerged. For instance, the infusion of ‘21st century skills’ into the foundations for science education carries with it strength of consensus (> 85.00%) that is equalled by the level of ill-definition the term has for many educators. As

has been pointed out, there is a re-emerging literature on 21st century skills in the last seven or eight years that remains somewhat of an unknown to many members participating in this study. This is why, in the between-round summaries provided to the panel members after Round 1, this was a terminology that could not specify one set of skills but could readily provide sample suites of skills sets that most could agree upon. The *Relevance of Science for Students* achieved a level of attention that reminded many of the classic ROSE Study conducted about a decade ago in the UK

New Consensus Positions for Canadian Science Education

The outcomes of this study provide important new directions, novel goals, a re-statement of the robustness of traditional foundational areas in science curriculum, and potentially significant change to the current architecture 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 be in alignment with certain other major developments in the OECD countries. Two examples of this would include STEM education and low levels of interest in the adoption of the *Next Generation Science Standards* (National Research Council, 2012; Achieve Incorporated, 2013). The following consensus positions have been identified from the Delphi forecasting of the expert panel (at the $\geq 70\%$ level):

- A. Consensus on four significant national and international trends that are expected to have high impact of the future of Canadian science education namely: Science and Education for Sustainability, Developing Scientific-

Oriented Skills, the Relevance of Science Education for Students, and Re-Conceptualizing the Purposes of Science Education;

- B. Consensus on a set of foundations for the science curriculum in Canada, which are: Science Education for Sustainability; Science, Technology, Society, and the Environment; Scientific Skills for the 21st Century, and the Nature of Science;
- C. Consensus on the principal goals for science education in Canada, including: Literacy in Science-Related Issues, Contributing to Human Health and Well-Being, Global Citizenship and Sustaining Earth's Systems, and Life-Long Learning in a Technology-rich Society;
- D. Consensus positions on: the roles and responsibilities of the stakeholders in science education; indicators for a Canadian approach in science education which accounts for: the circumpolar position of Canada; its indigenous peoples and their unique relationship to knowledge-keeping and to the landscape; addressing the problematic situation of Canada's indigenous peoples as underrepresented in the post-secondary and professional pathways of the sciences and the desire for more inter-jurisdictional cooperation in science education within the constraints of provincial electoral cycles and jurisdictional control of education systems in Canada.

Sustainability Sciences – A New Paradigm for Science Education?

It was argued from the literature in the opening chapter that Canada parted company with the enterprise of American science education with the advent of a strong curriculum emphasis more in alignment with Roberts's VISION II – that is, literacy in socio-scientific issues. The movement was uniquely devised by Canadian thinking and came into the curriculum commonplaces internationally as Science, Technology, and Society (STS science) in the mid-1970's. Within a

decade of that time STS has become rather accepted despite its continuing struggles for status against the traditions of academic rationalism. In the 1990's in Canada, the Pan-Canadian Framework adopted a major thread of STSE – adding an overt set of connections to the ‘environment’ to the original. For many, STSE approaches had claimed important new curriculum territory in Canadian schools, but the tension between it and VISION 1 science education created a mythical dichotomy that was never intended (MacPherson, 1995). I am offering now a conjecture that the post-constructivist anthropology recently advocated by Roy (2011) is capable of charting a course for, and seeking after a middle consensus between Roberts’ VISIONS I and II. This *rapprochement* and *détente* between the polarised forces of academic science and socio-scientific approaches may be possible with an entirely new approach to the edifice of science education in Canada – the *sustainability sciences*.

According to Clark and Dickson (2003), about a decade ago we were “witnessing the emergence of an array of increasingly vibrant movements to harness science and technology (S&T) in the quest for a transition towards sustainability” (p. 8059). Almost by definition, what was meant in their version of ‘sustainability’ was very simple – the reconciliation of society’s pace of development (the “anthropocentric”) with the planet’s environmental limits as a set of networked systems operating on the time scale of geology (the “biocentric”). Sustainability science is *not* environmental science but to conduct any science outside of an environmental context is not remotely conceivable. 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’s statement of 1999:

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

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; science education for a sustainable future was characterised by > 90% of the expert panel as what would be among uniquely Canadian contributions to international science education to 2030. Taken

together, along with the strength of the learning objectives described in the latter portion of Chapter 6, the Education for Sustainability (EfS) “curriculum of transformation” advocated by McDonald (2003) has now clearly been granted the credibility and status required to take action.

Sustainability Science, Technology, Economy and Environment (SSTEE)

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. I now introduce this new terminology – Sustainability Science, Technology, Economy and Environment (SSTEE) which is presented as a principal, guiding foundation for science education in Canada. The term provides historical continuity to the STSE movement which was a uniquely Canadian contribution to science education internationally. The term also exemplifies the defining characteristics of EfS which have been advocated by McDonald (2003), Babiuk & Falkenberg (2010), Murray (2012), and Sims and Falkenberg (2013). and SSTEE stands in opposition to the influences provided by the current trend of Science, Technology, Engineering and Mathematics (STEM). STSE has remained – for this expert community – the hallmark and defining characteristic of what it means to have a *Canadian approach* to science education. The quest continues.....to 2030 and well beyond.

Recommendations

At the outset, this study sought to resolve this core of its primary 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?”

The outcomes of the study has led to the framing of a number of recommendations, any one of which holds significance in the Canadian education system if seriously adopted and implemented. The jurisdictional control of science curriculum in Canada should not necessarily be an impediment to change but actually encourage collaboration and shared commitments. It has been 20 years since the CMEC instituted the processes which culminated in the Pan-Canadian Science Project. This was a project for which many in the expert panel held long-standing criticisms with respect to its design – especially that of tight bureaucratic control over its proclamations. Despite these criticisms (or perhaps because of them) a significant majority of the participants in this study have claimed that a much less bureaucratic process should take place if there is a next time around. Notwithstanding a less than perfect process, the panel recognizes the legitimate authority of the CMEC to take charge of any new national effort.

A popular view on any set of recommendations with respect to educational change in Canada is that the autonomy of the Provinces inevitably prohibits widespread implementation of any set of recommendations which are provided to its systems of education. In two recent interviews conducted as part of this study,

we can entertain some perspective on this apparent difficulty and see that the federation does not necessarily impede acceptance of new ways of doing things. One veteran curriculum policy researcher with more than 35 years of experience working with a provincial ministry (but not as an insider) in addition to many academic appointments put it this way:

Researcher: I would like to hear your perspectives on the question relating to the whole notion of whether in Canada – by virtue of the jurisdictional nature of education in a federation like Canada – will curriculum policy-making inevitably have to look to the realm of political processes to get things done?

2085PE: “Within Canada, we don’t do our policy-making on a national level; we do it on a provincial level because of our constitutional arrangements. So in Canada curriculum policy-making happens about 12 or 13 times independently for the most part rather than once as might be the case, say, in France which is a unitary country, and in fact the Canadian situation is replicated in many countries such as Germany, Australia, the United States and in other places where the country is not one single entity for educational purposes but has multiple entities. And so to consider curriculum policy-making on a provincial basis rather than a national basis is not as strange an idea as many Canadians have been led to think it is. It is actually a quite common occurrence and it is always political when you are doing it on a national basis or on a provincial basis. Dealing with the politics means “how do you reconcile different points of view when you have to come up with a single solution and when politics is generically reconciling multiple perspectives into a single response that can at least to some extent lead people to believe that their views have been taken into account?”...even if the answer at the end of the day is not the result or is not exactly what you would have chosen, it is nonetheless that the process has been respectful of your position.” (Text from interview with expert panel member 2085PE, April 28, 2014.)

Another member of the panel who also has many years of experience dealing with inter-provincial policy-making in science education strikes a similar tone with respect to the potential for the CMEC to initiate and energize the Canadian provinces with respect to a new vision for science education. However, this individual sees that CMEC role as in need of change both in terms of public profile and the degree to which it views science education as a priority area:

2001TE: “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 for education. However, there has to be political will within the jurisdictions that science education is important enough for discussion. Presently, the key activities that Ministers of Education have agreed upon to act are not explicitly related to science education.” (Text from interview with expert panel member 2001TE, May 1, 2014.)

Keeping in mind the caveats just mentioned, I present here a series of recommendations which are grounded in the consensus positions and opinion-making of the expert panel. As such, these are provisional in nature and should be viewed as starting points for discussion among the stakeholders and across the jurisdictions in Canada.

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.

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 presents a strong argument for commissioning a new phase of national discussions on the foundational purposes of science education within the Provinces;

Recommendation 3

- Together with its Provincial/Territorial partners, the panel encourages emergent commitments to a new vision for science education in Canada with consideration for a new foundation area in 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 (or strengthen existing) science education research traditions among five 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, the

Development of Science-Oriented Skills in New Learning Environments, the Relevance of Science Education for Students, First Nations', Métis and Inuit Perspectives and Traditional Knowledge-Keeping, 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 presented as a fruitful and 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.

It would be difficult after having conducted this study to not address the fundamental purposes of the maintenance of science education in Canada. There is tacit agreement that the enterprise can and should continue. How and why science education should continue will continue to be a matter of contested discussions. The expert panel had much to say about content, processes, rationale, and projections as to purpose(s). Perhaps the adjectival term “science education” can remain but with a sense that it may actually be “science *and* education”. To lend some support to this changing view we can look to perspectives provided in an interview conducted with a member of the panel following the Delphi rounds who was a career academic scientist. This question was articulated:

Researcher: I would like to ask you a question that may not have a great deal of specificity about it, but nonetheless here it is: “What, in your view, are the

chief purposes for science education in Canada as we go forward in the next generation?

2067PE: “Let me commence my response with a question of my own: “Why deliver science education at all?” The already oft-stated reasons all appear to still have some validity, but with a gaping omission. That omission relates to the understanding of the role of science in addressing what might well be considered as the greatest threat to the global society since the first humans demonstrated what might be said to be “behavioral modernity” emerging approximately 50,000 years ago. That threat is the steady erosion of the life-support systems of the planet by a non-sustainable, selectively globalized society. Evidence of this is clearly presented in the five-volume 2005 Millennium Ecosystem Assessment.

Science has a major role to play in addressing this challenge, but this is not explicitly identified as a reason for science education. Let me be absolutely clear on this point - the human species is presently on a trajectory that could have globally catastrophic outcomes; science has a role to play in reversing that trend; but is not explicitly seen as a pressing reason for science education. Why? I would submit that the principle reason lies in the serious impediments that accompany traditionally fragmented disciplines.” (Text from interview with expert panel member 2067PE, May 2, 2014).

When we look back over the trajectories of science education which were developed in Chapter 2, the notion of the “disciplines” of science is identifiable as one of the traditional hallmarks of education in the sciences for at least six decades. Integrating the sciences in an authentic manner or connecting it to the larger society has been an enduring problem with particularly unsatisfactory outcomes with respect to science education informing literacy demands. Attempts to solve the problems of the ‘fragmented disciplines’, academic rationalism,

Aboriginal perspectives, or just what to do about a socio-scientific issues approaches has inevitably led us to lower-status science in Canadian schools. High status science in schools is still embedded in and among a more traditional hierarchy of discipline-based areas of specialization.

The Delphi panel of experts assembled for this study has provided – in the spirit of the Pythia at our point of origin at Delphi, Greece – certain “oracles” which should provide impetus for further research, deliberative conferences, curriculum re-visioning and reconstruction, and actions among Canadian ministries of education and their educational partners. Unlike the ancient oracles which were obscure and indefinite, perhaps these have the character of being from sources of wisdom and are grounded in authoritative expressions of opinion.

References

- Abualrob, M. M., & Daniel, E. G. S. (2011). The Delphi technique in identifying learning objectives for the development of science, technology and society modules for Palestinian ninth grade science curriculum. *International Journal of Science Education*, (ahead of print) 1-21.
<http://dx.doi.org/10.1080/09500693.2011.610381>. Retrieved September 17, 2013.
- Abualrob, M.M. & Daniel, E. G. S. (2013). The Delphi Technique in identifying learning objectives for the development of science, technology and society modules for Palestinian ninth grade science curriculum, *International Journal of Science Education*, 35:15, 2538-2558, DOI: [10.1080/09500693.2011.610381](http://dx.doi.org/10.1080/09500693.2011.610381).
- Achieve, Inc. (2010). *International benchmarking report: Taking the lead in science education: Forging next-generation science standards*. Available online at <http://www.achieve.org/files/InternationalScienceBenchmarkingReport.pdf> . Retrieved January 22, 2013.
- Achieve, Inc. (2013). *Next generation science standards*. Available online at <http://www.nextgenscience.org/next-generation-science-standards>. Retrieved August 22, 2013.
- Aikenhead, G. S. (1980). *Science in social issues: Implications for teaching. A discussion paper, D-80/2*. Publications Office, Science Council of Canada, 100 Metcalfe St., Ottawa, Ontario K1P 5M.
- Aikenhead, G. S. (2000;[1999]). STS science in Canada: From policy to student evaluation. In D. Kumar, & D. Chubin (Eds.) *Science, technology, & society education: A resource book on research and practice*. Kluwer Academic Press (pp. 49-89).
- Aikenhead, G.S. (2006). *Science education for everyday life: Evidence-based practice*. New York. Teachers College Press.

- Aikenhead, G.S., Orpwood, G., & Fensham, P. (2011). Scientific literacy for a knowledge society. In C. Linder, L. Ostman, D.A. Roberts, P-O. Wickman, G. Erickson, & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (28-44). New York: Routledge, Taylor and Francis Group.
- Alberta Education (2014). “*Competencies for 21st Century Learning.*” Accessed May 7, 2014. Available online at: <http://education.alberta.ca/teachers/aisi/themes/21-century.aspx>.
- Al-Hadabi, A.S. (2007). Analysis of the environmental concepts in science textbooks of the basic education stage in the republic of Yemen (Unpublished doctoral dissertation). National University of Malaysia (UKM).
- American Association for the Advancement of Science (AAAS) (1989); *Science for all Americans*. New York: Oxford University Press.
- American Association for the Advancement of Science (AAAS) (1993); *Benchmarks for Science Literacy : Project 2061*. New York: Oxford University Press.
- American Association for the Advancement of Science (AAAS) (2000); Project 2061 Today. *Science Literacy for a Changing Future*, 10 (1).
- American Association for the Advancement of Science (AAAS) (2001); *Designs for Science Literacy*. New York: Oxford University Press.
- Amgen Canada, Inc. (2012). *Spotlight on science learning – A benchmark of Canadian talent*. Available online at: http://stream1.newswire.ca/media/2012/06/05/20120605_C5880_DOC_EN_14615.pdf . Retrieved January 15, 2013.
- Babiuk, G., & Falkenberg, T. (2010). *Sustainable development and living through changing teacher education and teaching in Manitoba*. Canada Council on Learning and Manitoba Education & Advanced Learning.

- Bazeley, P. (2002). The evolution of a project involving an integrated analysis of structured qualitative and quantitative data: from NUDIST 3 to NVivo. *International Journal of Social Research Methodology*, 5(3), 229-243.
- Bazeley, P. (2003). Computerized data analysis for mixed methods research. *Handbook of mixed methods in social and behavioral research*, 385-422.
- Bazeley, P. (2006). The contribution of computer software to integrating qualitative and quantitative data and analyses. *Research in the Schools*, 13(1).
- Bazeley, P. (2009). Analysing qualitative data: More than 'identifying themes'. *Malaysian Journal of Qualitative Research*, 2(2), 6-22.
- Bazeley, P., & Jackson, K. (Eds.). (2013). *Qualitative data analysis with NVivo*. Sage Publications Limited.
- Benton, D. C., González-Jurado, M. A., & Beneit-Montesinos, J. V. (2013). Defining nurse regulation and regulatory body performance: a policy Delphi study. *International Nursing Review*, 60(3), 303-312.
- Blades, D. (2013). Why most students don't choose STEM careers. PolicyMatters.ca. Available online at <http://www.policymatters.ca/opinion-pieces/why-most-students-dont-choose-stem-careers/> . Retrieved August 14, 2013.
- Bloch, M. (Mars) (2014). A qualitative study examining Ontario science curriculum policy from 1985 to 2008: Global influences, local political arenas, and curriculum reform. Unpublished PhD dissertation. The University of Roehampton / University of Surrey (UK). 440 pp.
- Bolte, C., Schulte, T., Kapanadze, M., & Slovinsky, E. (2012). Stakeholders' Views on Desirable Science Education in Georgia. *Student active learning in science*, 79-91.
- Bourdieu, P. (1990). *The Logic of Practice*. Cambridge: Polity Press.
- Brown, B., Cochran, S.W. and Dalkey, N. C. (1969, January). The Delphi method: An experimental study of group opinion. Delphi II, Structure of Experiments. RAND

Corporation Research Memorandum RM-5957-PR. Retrieved June 11, 2013, from http://www.rand.org/pubs/research_memoranda/RM5957.html

- Byrnes, V. (2009). Getting a feel for the market: The use of privatized school management in Philadelphia. *American Journal of Education, 115*(3), 437-455.
- (Government of Alberta) and Cameron, D. (1959). The Royal Commission to Inquire into Matters Connected with Petroleum and Petroleum Products. *Report of the Royal Commission on Education in Alberta*.
- Chaney, B. H., Eddy, J. M., Dorman, S. M., Glessner, L. L., Green, B. L., & Lara-Alecio, R. (2009). A primer on quality indicators of distance education. *Society for Public Health Education, 10*(2), 222-231.
- Chappell, T. (2013). Plato on knowledge in the *Theaetetus*. The Stanford Encyclopedia of Philosophy (Winter 2013 Edition). Edward N. Zalta (ed.). Online at: <http://plato.stanford.edu/archives/win2013/entries/plato-theaetetus/> . Retrieved October 7, 2014.
- Clark, W. C., & Dickson, N. M. (2003). Sustainability science: the emerging research program. *Proceedings of the National Academy of Sciences, 100*(14), 8059-8061.
- Clayton, M. J. (1997). Delphi: a technique to harness expert opinion for critical decision-making tasks in education. *Educational Psychology, 17*(4), 373-386.
- Clinton, W. J., & Gore Jr, A. (1994). *Science in the national interest*. Executive Office of the President, Washington, DC.; Office of Science and Technology, Washington, DC.
- Clough, M. P. (2011). The story behind the science: Bringing science and scientists to life in post-secondary science education. *Science & Education, 20*(7-8), 701-717.
- Cole, R. M. (2012). *Looking to the future: A Delphi study forecasting the use of social technology tools and applications in PreK-12 teaching and learning over the next five years*. (Order No. 3539540, Saint Louis University). *ProQuest Dissertations and Theses*, , 111. Retrieved from

<http://search.proquest.com/docview/1095560094?accountid=14569>.
(1095560094) on October 6, 2013.

Collins, A. (1995). National science education standards in the United States: A process and a product. *Studies in Science Education*, 26(1), 7-37.
doi:10.1080/03057269508560069 .

Collins, S., Osborne, J., Ratcliffe, M., Millar, R., & Duschl, R. (2001). What 'ideas-about-science' should be taught in school science? A Delphi study of the expert community. Paper presented at the American Educational Research Association (AERA) national conference. Seattle, WA, April 2001. 28 pp. Accessed December 28, 2013 from: <http://eprints.soton.ac.uk/58275/> .

Connelly, F. M. (1971). Some considerations on the status, relationship to research, character, and study of curriculum development: An overview. *Curriculum Theory Network*, (7), 164-173.

Connelly, F. M. (1972). The functions of curriculum development. *Interchange*, 3(2), 161-177.

Connelly, F. M., & Clandinin, D. J. (1988). *Teachers as curriculum planners. narratives of experience*. New York: NY. Teachers College Press. 231 pp.:

Connelly, F. M., & Connelly, G. (2013). Curriculum policy guidelines. In Luke, A., Woods, A., & Weir, K. (Eds.). *Curriculum, Syllabus Design and Equity: A Primer and Model*, 6. pp. 54-73.

Connelly, F. M., & Orpwood, G. W. F. (1977). Science education: Trends without data and data without trends. *The Review of Education/Pedagogy/Cultural Studies*, 3(2), 81-101.

Council of Canadian Academies (2012). The state of science and technology in Canada, 2012. The Expert Panel on the State of Science and Technology in Canada. Ottawa: CCA. 232 pp. Available online at:

[http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%](http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20)

[20and%20news%20releases/sandt_ii/stateofst2012_fullreporten.pdf](#) . Retrieved August 15, 2013.

Council of Canadian Academies (CCA) (2014). Science culture: Where Canada stands. The Expert Panel on the State of Canada's Science Culture. Ottawa: CCA. 222 pp. Available online at: <http://www.scienceadvice.ca/en/publications/assessments.aspx> . Retrieved September 28, 2014.

Council of Ministers of Education, Canada (CMEC), Haggerty, S. M., & Hobbs, E. D. (1981). Curriculum Committee. *Analysis of science curricula in the provinces*.

Council of Ministers of Education, Canada (CMEC) (1993). *Victoria Declaration 1993*. Toronto, Ontario: Author. Retrieved from <http://www.cmec.ca/Publications/Lists/Publications/Attachments/251/victoria-declaration-1993.pdf> August 18, 2013.

Council of Ministers of Education, Canada (CMEC) (1997). *Common framework of science learning outcomes: Pan-Canadian protocol for collaboration on school curriculum*. Retrieved May 30, 2012. 261pp. Available online at: <http://publications.cmec.ca/science/framework/>

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications Incorporated.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches*. Sage.

Corbin, J., and Strauss, A. (Eds.). (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage Publications.

Dalkey, N.C. (1967). Delphi. RAND Corporation Document P-3704. Retrieved April 29, 2014 from <http://www.rand.org/pubs/papers/P3704.html>. 10 pp.

Dalkey, N. C. and O. Helmer-Hirschberg (1963). An experimental application of the Delphi method to the use of experts. *Management Science*, 9, 10.

- Dalkey, N.C., Bernice B. Brown, S.W. Cochran (1970). The Delphi method IV: Effect of percentile feedback and feed-in of relevant facts. RAND Corporation Research Memorandum RM-6118-PR. Retrieved April 29, 2014 from http://www.rand.org/pubs/research_memoranda/RM6118.html .
- Dalkey, N. Rourke, D. Lewis, and R. Snyder, D.(1972). In N. Dalkey (Ed.) *Studies in quality of life: Delphi and decision making*. Lexington Books.
- DeBoer, G. E. (2011). The globalization of science education. *Journal of Research in Science Teaching*, 48(6), 567-591.
- Delbecq, A. L., & Van de Ven, A. H. (1971). A group process model for problem identification and program planning. *The Journal of Applied Behavioral Science*, 7(4), 466-492
- Delbecq, A. L., Van de Ven, A. H., & Gustafson, D. H. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*. Glenview, IL: Scott, Foresman.
- DeWitt, N. (1954). Professional and scientific personnel in the U.S.S.R.. *Science*, 120(3105)1-4.
- DeWitt, N. (1955). *Soviet professional manpower: Its education, training, and supply*. Washington, D.C.: National Science Foundation.
- DeWitt, N. (1961). *Education and Professional Employment in the USSR* (Vol. 61, No. 40). National Academies.
- Dillman, D. A., Phelps, G., Tortora, R., Swift, K., Kohrell, J., Berck, J., & Messer, B. L. (2009). Response rate and measurement differences in mixed-mode surveys using mail, telephone, interactive voice response (IVR) and the Internet. *Social Science Research*, 38(1), 1-18.
- Ecken, P., Gnatzy, T., & von der Gracht, H. A. (2011). Desirability bias in foresight: Consequences for decision quality based on Delphi results. *Technological*

Forecasting and Social Change, 78(9), 1654-1670. doi:
10.1016/j.techfore.2011.05.006.

Estevez, K. D. (2011). *Preparing our nation's youth for success in the 21st century: A case study on the implementation of globalization in educational practices and curriculum*. PhD Dissertation, The University of Southern California. *ProQuest Dissertations and Theses*, Retrieved from
<http://search.proquest.com/docview/884311257?accountid=14569> .

FarrELL, L. (2010). Pierre Bourdieu on European identity: Theories of habitus & cultural capital. *Social and Political Review*, 20, 107-115.

Fensham, P. J. (2002). Time to change drivers for scientific literacy. *Canadian Journal of Math, Science & Technology Education*, 2(1), 9-24.

Fensham, P. J. (2009). The link between policy and practice in science education: The role of research. *Science Education*, 93, 1076 – 1095.

Fensham, P. J. (2011). Globalization of science education: Comment and commentary. *Journal of Research in Science Teaching*, 48(6), pp. 698-709.

Fensham, P. J. (2012). The science curriculum: The decline of expertise and the rise of bureaucratise. *Journal of Curriculum Studies*, p. 1-17.
<http://dx.doi.org/10.1080/00220272.2012.737862>. Accessed January 14, 2013.

Franklin, K. K., & Hart, J. K. (2007). Idea generation and exploration: Benefits and limitations of the policy Delphi research method. *Innovative Higher Education*, 31(4), 237-246.

Fullan, M, (2013). “*Great to Excellent: Launching the Next Phase of Ontario’s Education Agenda*.” Accessed May 7, 2014. Available online at:
http://www.michaelfullan.ca/wp-content/uploads/2013/09/13_Fullan_Great-to-Excellent.pdf .

Gardiner, D.P. & 17 others (1983). *A nation at risk: The imperative for educational reform. An open letter to the American people*. National Commission on Excellence in Education. April, 1983. 31 pp. Available online at:

<http://cc.usst.edu.cn/Download/b42c4210-e82c-4244-aa4f-89d2b313f44a.doc>.
Retrieved August 16, 2012.

- George, D.A. (1981). *An engineer's view of science education*. . A discussion paper. Science Council of Canada. Publications Office, Science Council of Canada, 100 Metcalfe St., Ottawa, Ontario K1P 5M1.
- Goldschmidt, P. G. (1975). Scientific inquiry or political critique?: Remarks on Delphi assessment, expert opinion, forecasting, and group process by H. Sackman. *Technological Forecasting and Social Change*, 7(2), 195-213.
- Gorghiu, L. M., Gorghiu, G., Olteanu, R. L., Dumitrescu, C., Suduc, A. M., & Bizoi, M. (2013). Delphi Study-A Comprehensive Method for Outlining Aspects and Approaches of Modern Science Education. *Procedia - Social and Behavioral Sciences*, 83, 535-541.
- Gupta, U. G., & Clarke, R. E. (1996). Theory and applications of the Delphi technique: A bibliography (1975–1994). *Technological Forecasting and Social Change*, 53(2), 185-211. doi: 10.1016/S0040-1625(96)00094-7 .
- Harris, I. (1991). Deliberative inquiry: The arts of planning. In E. C. Short (Ed.), *Forms of curriculum inquiry*. New York: NY: State University of New York Press, pp. 285-308.
- Hass, C. G. (1961). Who should plan the curriculum? *Educational Leadership*, October, 1961, 2-6.
- Hasson, F., & Keeney, S. (2011). Enhancing rigour in the Delphi technique research. *Technological Forecasting and Social Change*, 78(9), 1695-1704.
- Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, 32(4), 1008-1015.
- Helmer, O. (1983). *Looking forward: A guide to futures research*. Beverly Hills, CA: Sage Publications

- Helmer-Hirschberg, O. (1966). The use of the Delphi technique in problems of educational innovations. . RAND Corporation: Santa Monica, CA. ERIC No. ED014134.
- Helmer-Hirschberg, O. (1967). *Analysis of the future: The Delphi Method*. (No. RAND-P-3558). RAND Corporation: Santa Monica, CA.
- Herron, M. D. (1971). The nature of scientific enquiry. *School Review*, 79, 171-212.
- Hodson, D. (2002). Some thoughts on scientific literacy: Motives, meanings and curriculum implications. *Asia-Pacific Forum on Science Learning and Teaching*, 3(1) 1-20.
- Hodson, D. (2007). What is scientific literacy and why do we need it? *Multiple Perspectives on Education and Society in Newfoundland and Labrador*.
- Holdaway, E.A., Deblois, C., & Winchester, I.S. (1994). Practices and opinions reported by coordinators of graduate programs. *Interchange*, 25(1), 65-86.
- Holdaway, E.A., Deblois, C., & Winchester, I.S. (1995). Supervision of graduate students. *The Canadian Journal of Higher Education*, 25(3), 1-29.
- Holey, E. A., Feeley, J. L., Dixon, J., & Whittaker, V. J. (2007). An exploration of the use of simple statistics to measure consensus and stability in Delphi studies. *BMC Medical Research Methodology*, 7, 52-52. doi: 10.1186/1471-2288-7-52 .
- Hsu, C. C., & Sandford, B. A. (2007a). Minimizing non-response in the Delphi process: How to respond to non-response. *Practical Assessment, Research & Evaluation*, 12(17), 62-78. Retrieved from <http://www.pareonline.net/pdf/v12n17.pdf> .
- Hsu, C.C., & Sandford. B.A. (2007b), "The Delphi Technique: Making Sense Of Consensus". *Practical Assessment, Research & Evaluation*, 12(10), 1-8. Retrieved from <http://www.pareonline.net/pdf/v12n10.pdf> .
- Hurd, P. DeH. (1958). Science literacy: Its meaning for American schools. *Educational Leadership*, 16(1), 13-16.

- Jenkins, E. W., & Pell, R. G. (2006). *The Relevance of Science Education Project (ROSE) in England: a summary of findings*. Leeds: Centre for Studies in Science and Mathematics Education, University of Leeds.
- Johnson, P. G. (1962). The goals of science education. *Theory into Practice*, 1(5), 239-244.
- Jolly, J. L. (2009). Historical perspectives: The National Defense Education Act, the current STEM initiative, and the gifted. *Gifted Child Today*, 32(2), 50.
- Judd, R.C. (1971). *Delphi decision methods in higher education administration*. Paper presented at the 12th American Meeting of the Institute of Management Sciences, Detroit.
- Judd, R. C. (1972). Use of Delphi methods in higher education. *Technological Forecasting and Social Change*, 4(2), 173-186.
- Juniper, E. F., Guyatt, G. H., Streiner, D. L., & King, D. R. (1997). Clinical impact versus factor analysis for quality of life questionnaire construction. *Journal of Clinical Epidemiology*, 50(3), 233-238.
- Kaiser, D. (2006). The physics of spin: Sputnik politics and American physicists in the 1950s. *Social Research*, 73(4), 1225-1252.
- Keeney, S., McKenna, H., & Hasson, F. (2010). *The Delphi technique in nursing and health research*. John Wiley & Sons.
- Keeney, S.; Hasson, F.; McKenna, H. (2006) Consulting the oracle: Ten lessons from using the Delphi technique in nursing research. *Journal of Advanced Nursing*, 53(2), 205-212.
- Keeney, S., Hasson, F., & McKenna, H. (2011a). The Delphi Technique. *The Delphi Technique in Nursing and Health Research*, 1-17. John Wiley & Sons.
- Keeney, S., Hasson, F., & McKenna, H. (2011b). Conducting Research Using the Delphi Technique. *The Delphi Technique in Nursing and Health Research*, 69-83. John Wiley & Sons.

- King, Russel J. (2008). A decision-making framework for total ownership cost management of complex systems: A Delphi study. Unpublished PhD dissertation, The University of Phoenix. 180 pp.
- Klassen, S. (2009). The construction and analysis of a science story: A proposed methodology. *Science & Education*, 18(3-4), 401-423.
- Klopfert, L. E. (1969). Science education in 1991. *The School Review*, 77(3/4), 199-217.
- Komiyama, H., Takeuchi, K., Shiroyama, H., & Mino, T. (Eds.). (2011). *Sustainability science: A multidisciplinary approach*. United Nations University.
- Korol, A. (1957). *Soviet education for science and technology*. Cambridge, MA: MIT Press.
- Krige, J. (2000). NATO and the strengthening of western science in the post-Sputnik era. *Minerva*, 38(1), 81-108.
- Landeta, J. (2006). Current validity of the Delphi method in social sciences. *Technological Forecasting and Social Change*, 73(5), 467-482. doi: 10.1016/j.techfore.2005.09.002
- Landeta, J., Barrutia, J., & Lertxundi, A. (2011). Hybrid Delphi: a methodology to facilitate contribution from experts in professional contexts. *Technological Forecasting and Social Change*, 78(9), 1629-1641.
- Levin, B. (2001) *Reforming education: From origins to outcomes*. London: Routledge Falmer.
- Levin, B. (2007) 'Sustainable, large-scale education renewal', *Journal of Educational Change*, 8 (4), pp.323-336.
- Levin, B. (2008) *How to change 5000 schools; A practical and positive approach for leading change at every level*. Cambridge, MA: Harvard Education Press.
- Linstone, H. A. and Turoff, M. (eds.) (2002;[1975]). *The Delphi method: Techniques and applications*. Reading, MA. Addison-Wesley Pub. Co. Available online (2002 re-issue) at: <http://is.njit.edu/pubs/delphibook/> . Retrieved March 25, 2013.

- Linstone, H. A., & Turoff, M. (2011). Delphi: A brief look backward and forward. *Technological Forecasting and Social Change*, 78(9), 1712-1719.
- Liu, X. (2013). Expanding notions of scientific literacy: A reconceptualization of aims of science education in the knowledge society. In *Science Education for Diversity* (pp. 23-39). Springer Netherlands.
- Livermore, A. H. (1964). The process approach of the AAAS Commission on Science Education. *Journal of Research in Science Teaching*, 2, 271-282.
- Ludwig, B. (1997). Predicting the future: Have you considered using the Delphi methodology? *Journal of Extension*, 35(5), 1-4. Available online at <http://www.joe.org/joe/1997october/tt2.php/index.php> . Retrieved August 20, 2013.
- MacPherson, E. D. (1995). Chaos in the curriculum. *Journal of Curriculum Studies*, 27(3), 263-279.
- MacPherson, E. D. (1997). Chaos in the curriculum: A rejoinder to Hunter and Benson. *Journal of Curriculum Studies*, 29(1), 101-104.
- MacPherson, E. D. (1999). Metaphors and social science. *Discrete Dynamics in Nature and Society*, 3, 65-68.
- Marchais-Roubelat, A., & Roubelat, F. (2011). The Delphi method as a ritual: Inquiring the Delphic Oracle. *Technological Forecasting and Social Change*, 78(9), 1491-1499.
- Martino, J. P. (1972a). Forecasting the progress of technology. *An Introduction to Technological Forecasting*, 1, 13.
- Martino, J. P. (1972b). *An introduction to technological forecasting*. Taylor & Francis, US.
- Martino, J. P. (1972c). Tools for looking ahead. *Spectrum, IEEE*, 9(10), 32-40.

- McDonald, C. (2003). *Engaging a grade six teacher and her students in educating for sustainability: A teacher-researcher collaborative study*. Unpublished PhD Dissertation. The University of Manitoba. 425 pp.
- McKenna, H. P. (1994). The Delphi technique: a worthwhile research approach for nursing? *Journal of Advanced Nursing*, 19(6), 1221-1225.
- Metz, D., Klassen, S., McMillan, B., Clough, M., & Olson, J. (2007). Building a foundation for the use of historical narratives. *Science & Education*, 16(3-5), 313-334.
- Mieczkowski, Y. (2013). *Eisenhower's Sputnik moment: The race for space and world prestige*. Cornell University Press.
- Milford, T.M., Jagger, S., Yore, L.D. & Anderson, J.O. (2010) National influences on science education reform in Canada, *Canadian Journal of Science, Mathematics and Technology Education*, 10:4, 370-381, DOI: [10.1080/14926156.2010.528827](https://doi.org/10.1080/14926156.2010.528827) . Available online at: <http://dx.doi.org/10.1080/14926156.2010.528827> . Accessed September 18, 2012.
- Miller, L. E. (2006). Determining what could/should be: The Delphi technique and its application. Paper presented at the 2006 annual meeting of the Mid-Western Educational Research Association, Columbus, OH.
- Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.
- Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future. The report of a seminar series funded by the Nuffield Foundation*. London: King's College London, School of Education.
- Mitchell, V. W. (1991). The Delphi technique: An exposition and application. *Technology Analysis & Strategic Management*, 3(4), 333-358.

- Munby, H. (1982). The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. *Instructional science*, 11(3), 201-225.
- Murray, J.J. (2012). *The Complexity Sciences: A New Curricular Foundation in Education for Sustainable Development?* Proceedings of the Educating for Sustainable Well-Being: Concepts, Issues, Perspectives, and Practices Conference. University of Manitoba. 24 November, 2012. 67 pp.
- Murry, J.W., Jr. & J.O. Hammons (1995). Delphi: A versatile methodology for conducting qualitative research. *Review of Higher Education*, 18, 423-436.
- Myers, T. D. (2007). Learning outcomes for an engineering and technology public policy curriculum (Unpublished doctoral dissertation). The Ohio State University.
- Nadeau, R., & Désautels, J. (1984). *Epistemology and the teaching of science*. Publications Office Science Council of Canada. Science Council of Canada, 100 Metcalfe St., Ottawa, Ontario K1P 5M1.
- National Research Council (NRC) (1996). *National science education standards*. Washington, D.C.: National Academy Press.
- National Research Council (NRC) (1999). *Our Common Journey*. National Academy Press, Washington, DC.
- National Research Council (NRC) (2012). *National science education standards*. Washington, D.C.: National academy press. 262 pp. Retrieved May 30, 2012, from <http://www.nap.edu/readingroom/books/nses/html/6e.html> .
- National Science Teachers' Association (NSTA). (1964). *Theory into action in science curriculum development*. National Science Teachers Association, Curriculum Committee. Washington, D.C..
- National Science Teachers' Association (NSTA) (2012). *Recommendations on next generation science standards: First public draft*. Available online from <http://www.nsta.org/about/standardsupdate/resources/NSTARRecommendationsToAchieveOnMay2012PublicDraft.pdf> . Retrieved August 10, 2012.

- Neal, H. A., Smith, T. L., & McCormick, J. B. (2008). *Beyond Sputnik: US science policy in the twenty-first century*. University of Michigan Press.
- O'Brien, P. W. (1979). *Doctoral planning studies: A state of the art examination*. Flinders University of South Australia, School of Education Research Seminar. Unpublished manuscript.
- Orpwood, G. W. F. (1981). *The logic of curriculum policy deliberation: An analytic study from science education*. (Unpublished PhD Dissertation). University of Toronto, Toronto: ON. (ED 211 372)
- Orpwood, G. W. F. (1983a). Deliberative inquiry: The study of politics and practice in Canadian science education. *Paper Presented at the Annual Meeting of the American Educational Research Association*, Montreal, Quebec.
- Orpwood, G. W. F. (1983b). Defensible roles for researchers in curriculum policymaking. *The Journal of Educational Thought*, 17(3), 221-229.
- Orpwood, G. W. F. (1985). Toward the renewal of Canadian science education. I. Deliberative inquiry model. *Science Education*, 69(4), 477-489.
- Orpwood, G., & Barnett, J. (1997). Science in the national curriculum: An international perspective. *The Curriculum Journal*, 8(3), 331-349.
- Orpwood, G.W.F., & Alam, I. (1984). *Science education in Canadian schools: Volume 2; Statistical database for Canadian science education. Background Study 52*. Hull: Quebec: Minister of Supply and Services.
- Orpwood, G. W. F., & Souque, J. P. (1984). *Science education in Canadian schools. Summary of background study 52*. Science Council of Canada, Ottawa: ON.
- Orpwood, G. W. F., & Souque, J. P. (1985). Toward the renewal of Canadian science education. II. Findings and recommendations. *Science Education*, 69(5), 625-636.
- Orpwood, G. W.F., Schmidt, B. A., & Jun, H. (2012). *Competing in the 21st century skills race*. Canadian Council of Chief Executives / Conseil canadien des chefs d'entreprise. Available online at

<http://www.canadianopenlibrary.ca/SwfDocs/235/235164.pdf> . Accessed August 14, 2013.

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education*, 23(5), 441-467.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What “ideas-about-science” should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40(7), 692-720.

Osgood C.E. (1964). Semantic differential technique in the comparative study of cultures. *American Anthropologist*, 66(3), 171–200.

Page, J. E. (1979). *A Canadian context for science education*. A discussion paper. Science Council of Canada. Publications Office, Science Council of Canada, 100 Metcalfe St., Ottawa, Ontario K1P 5M. 52 pp.

Page, J. E. (1981). *Reflections on the Symons report: The state of Canadian studies in 1980: A report*. Secretary of State. Ottawa: ON. 236 pp.

Paiva, J., Morais, C., & Barros, J. (2012). *Curricular Delphi study on science education*. PROFILES – WP3: Stakeholders Involvement and Interaction. Interim Report on the Second Round of the UP Working Group. Available online at http://www.profiles.org.pt/wp-content/uploads/2011/09/Report_PT_delphi_2nd-round_FINAL.pdf . Retrieved August 18, 2013.

Partnership for 21st Century Skills (2007). www.21stcenturyskills.org.

Passow, A. H. (1957). The talented youth project: A report on research under way. *Educational Research Bulletin*, 199-216.

Passow, A. H. (1993). Recognizing excellence in education: Teachers and teacher education. *The Educational Forum*, , 57(3) 284-293.

- Passow, A. H., Beasley, J. E., & Brooks, D. J. (1957). Adapting the curriculum to the needs, capabilities, and talents of individual students. *Review of Educational Research*, 27(3), 277-286.
- Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, Inc.
- Patton, M. Q. (2002). Two decades of developments in qualitative inquiry: A personal, experiential perspective. *Qualitative Social Work*, 1(3), 261-283.
- Peddiwell, J. A. (1939). *The saber-tooth curriculum*. (1st ed.). New York: NY: McGraw-Hill Book Co.
- Pinar, W.F. (2008). Introduction to a Common Countenance. *Journal of the Canadian Association for Curriculum Studies*. Vol. 8 (2). 129 – 155.
- Plato (380 BCE;2009). *Meno*. Translated by B. Jowett. Internet Classics Archive by Daniel C. Stevenson, Web Atomics. Massachusetts Institute of Technology. Online at: <http://classics.mit.edu/Plato/meno.html> . Accessed October 3, 2014.
- Powell, C. (2003). The Delphi technique: Myths and realities. *Journal of Advanced Nursing*, 41(4), 376-382.
- Rath, G., & Stoyanoff, K. (1983). The Delphi technique. In F. L. Ulschak (Ed.), *Human resource development: The theory and practice of need assessment* (pp. 111-131). Reston, VA: Reston.
- Rauch, W. (1979). The decision Delphi. *Technological Forecasting and Social Change*, 15(3), 159-169.
- Reid, W. A. (1979). Practical reasoning and curriculum theory: In search of a new paradigm. *Curriculum Inquiry*, 9, 187-207.
- Reid, W. A. (1981). The deliberative approach to the study of the curriculum and its relation to critical pluralism. *Rethinking Curriculum Studies*, 160-187.

- Reid, W.A. (1982). Deliberative curriculum theory: A manifesto. *American Educational Research Association Annual Meeting, New York.1982.*
- Reid, W. A. (1988). The institutional context of curriculum deliberation. A research agenda. *Journal of Curriculum and Supervision, 4(1), 3-16.*
- Reid, W. A. (1998). OP-ED: Erasmus, Gates, and the end of curriculum. *Journal of Curriculum Studies, 30(5), 499-501.*
- Rice, K. (2009). Priorities in K-12 Distance Education: A Delphi Study Examining Multiple Perspectives on Policy, Practice, and Research. *Educational Technology & Society, 12(3), 163-177.*
- Rieger, W. G. (1986). Directions in Delphi developments: Dissertations and their quality. *Technological Forecasting and Social Change, 29(2), 195-204.*
- Risi, M. (1982). *Macroscop: A holistic approach to science teaching.* A discussion paper. Science Council of Canada. Publications Office, Science Council of Canada, 100 Metcalfe St., Ottawa, Ontario K1P 5M1.
- Roberts, D. A. (1982). Developing the concept of “curriculum emphases” in science education. *Science Education, 66(2), 243-260.*
- Roberts, D. A. (1983). *Scientific literacy: Towards balance in setting goals for school science programs. A discussion paper.* Toronto: ON: Guidance Centre, University of Toronto.
- Roberts, D. A. (1988). What counts as science education. In P. Fensham (Ed.) *Development and Dilemmas in Science Education, 27-54.*
- Roberts, D.A. (2007) Scientific literacy/science literacy. In Abell, S. and Lederman, L. (eds.) *Handbook of research on science education.* Hillsdale, NJ: Lawrence Erlbaum Publishers, Ltd., pp.729-780.
- Roberts, D.A. (2011). Competing visions of scientific literacy: The influence of a science curriculum policy image. In Linder, C., Östmaan, L., Roberts, D., Wickman, P-

O., Erickson, G., and MacKinnon, A. (eds.) *Exploring the landscape of scientific literacy*. New York: Routledge, pp.11-27.

Rotondi, A., & Gustafson, D. (1996). Theoretical, methodological and practical issues arising out of the Delphi method. In Adler, M. and Ziglio, E. (Eds.) *Gazing into the Oracle: the Delphi method and its application to social policy and public health*. pp. 34-55.

Rundgren, C. J., & Chang Rundgren, S. N. (2012). A Delphi Study in Sweden: Probing Different Stakeholders' Viewpoints on Science Education. In *Inquiry-based Science Education in Europe: Reflections from the PROFILES Project* (pp. 177-178). Alpen-Adria-Universität.

Rutherford, J. & Ahlgren, A.,(eds.) (1989). *Science for all Americans*. AAAS Publications.

Rutherford, M. (1997a). *American institutionalism and the history of economics*. Cambridge University Press.

Rutherford, M. (1997b). American Institutionalism and the History of Economics. *Journal of the History of Economic Thought*, 19(02), 178-195.

Rutledge, J. A. (1973). What has happened to the " new " science curricula?. *Educational Leadership*, 30(7), 600-603.

Sackman, H. (1974a). *Delphi assessment: Expert opinion, forecasting, and group process* (No. RAND-R-1283-PR). RAND Corporation. Santa Monica, CA. Available online at: <http://www.rand.org/pubs/reports/R1283.html>. 125 pp.

Sackman, H. (1974b). *Delphi critique; expert opinion, forecasting, and group process* (RAND Report No. R-1283-PR). Lexington, Mass.,: Lexington Books.

Scapolo, F., & Miles, I. (2006). Eliciting experts' knowledge: A comparison of two methods. *Technological Forecasting and Social Change*, 73(6), 679-704.

- Schneider, J. B. (1972). The Policy Delphi: a regional planning application. *Technological Forecasting and Social Change*, 3, 481-497.
- Schulte, T., & Bolte, C. (2012). European Stakeholders' Views on Inquiry Based Science Education—Method of and Results from the International PROFILES Curricular Delphi Study on Science Education Round. *Inquiry based Science Education in Europe-First Examples and Reflections from the PROFILES Project*, 42-51.
- Schwab, J. J. (1969). The practical: A language for curriculum. *The School Review*, 78(1), 1-23.
- Schwab, J. J. (1971). The practical 2: Arts of eclectic. *The School Review*, 79(4), 493-542.
- Schwab, J. J. (1973). The practical 3: Translation into curriculum. *The School Review*, 81(4), 501-522.
- Science Council of Canada (SCC). (1984a). *Science education in Canadian schools, Volume 1: Introduction and curriculum analyses. Background Study 52*. Hull: Quebec: Minister of Supply and Services, Canada.
- Science Council of Canada (SCC). (1984b). *Science education in Canadian schools: Volume 2; Statistical database for Canadian science education. Background Study 52*. Hull: Quebec: Minister of Supply and Services.
- Science Council of Canada (SCC). (1984c). *Science for every student: Educating Canadians for tomorrow's world. Summary of Report 36*. Hull: Quebec: Minister of Supply and Services, Canada.
- Shamos, M. H. (1995). *The myth of scientific literacy*. Rutgers University Press.
- Shelton, K. (2010). *A quality scorecard for the administration of online education programs: A Delphi study*. Ph.D. Dissertation, The University of Nebraska - Lincoln. *ProQuest Dissertations and Theses*. (No. 759782268).
- Short, E. C. (1991). *Forms of curriculum inquiry*. State University of New York Press.

- Sims, L., & Falkenberg, T. (2013). Developing competencies for education for sustainable development: A case study of Canadian faculties of education. *International Journal of Higher Education*, 2(4).
- Sinha I.P., Smyth R.L. & Williamson P.R. (2011). Using the Delphi technique to determine which outcomes to measure in clinical trials: Recommendations for the future based on a systematic review of existing studies. *PLoS Medicine* 8(1): e1000393. doi:10.1371/journal.pmed.1000393. Retrieved October 14, 2014.
- Sinkovics, R. and Alfoldi, E.A. (2012). Progressive focusing and trustworthiness in qualitative research: The enabling role of computer-assisted qualitative data analysis software (CAQDAS). *Management International Review*, 52(6), 817-845. (DOI: 10.1007/s11575-012-0140-5).
- Skulmoski, G.J. & Hartman, F.T. (2002). The Delphi method: Researching what does not exist (yet). Proceedings of the *International Research Network on Organization by Projects, IRNOP V Conference*, Renesse, The Netherlands.
- Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi method for graduate research. *Journal of information technology education*, 6, 1.
- Solomon, J., & Aikenhead, G. (Eds.). (1994). *STS education: International perspectives on reform*. New York: NY: Teachers College Press.
- Spalding, W. B. (1958). Satellites, rockets, missiles: Their meaning for education. *Educational Leadership*, June 11, 2012.
- Steinert, M. (2009). A dissensus based online Delphi approach: An explorative research tool. *Technological Forecasting and Social Change*, 76(3), 291-300. doi: 10.1016/j.techfore.2008.10.006.
- Stewart, D. W., & Shamdasani, P. N. (1990). Focus groups: Theory and practice. Applied social research methods series. *Focus Groups: Theory and Practice Applied Social Research Methods Series*.
- Stewart, J. (2001). Is the Delphi technique a qualitative method? *Medical Education*, 35(10), 922-923.

- Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.
- Strauss, A., & Corbin, J. (1994). Grounded theory methodology: An overview. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273-285). Thousand Oaks, CA: Sage.
- Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage.
- Sumsion, T. (1998). The Delphi technique: An adaptive research tool. *British Journal of Occupational Therapy*, 61(4), 153-156.
- Surowiecki, J. (2004). The wisdom of crowds: Q & A with James Surowiecki. *The Wisdom of Crowds*. Author's Website. Retrieved October 6, 2013, from <http://www.randomhouse.com/features/wisdomofcrowds/Q&A.html>
- Sutherland, D. (2013). *Secondary Science Instruction and Student Diversity*. Draft manuscript, in review.
- Sutherland, N. (2008; [1986]). Foreword to George S. Tomkins' *A common countenance: Stability and change in the Canadian curriculum* (x-xiv). Scarborough, ON: Prentice-Hall Canada.
- Sweigert, Jr, R. L., & Schabacker, W. H. (1974). The Delphi technique: How well does it work in setting educational goals. Paper presented at the Annual Meeting of the American Educational Research Association (Chicago, Illinois, April, 1974). Atlanta, GA: Georgia State Board of Education.
- Syed, A. M., Hjarnø, L., Krumkamp, R., Reintjes, R., & Aro, A. R. (2010). Developing policy options for SARS and SARS-like diseases—a Delphi study. *Global Public Health*, 5(6), 663-675.

- Symons, T. H. B. (1975; [1978]). *To know ourselves: The report of the commission on Canadian studies*. Ottawa ON: Association of Universities and Colleges of Canada.
- Tomkins, G.S. (2008; [1986]). *A common countenance: Stability and change in the Canadian curriculum*. Scarborough, ON: Prentice-Hall Canada.
- Trna, J., & Krejčí, J. (2012). Web Support of Experiments. In Costa, MF, Dorio, BV, Erdogan, M. Erantay, N. (Eds.). *Proceedings of the 9th International Conference on Hands-on Science. Antalya, Turkey*: Akdeniz Univerzity, Antalya, Turkey (pp. 203-206).
- Turner, S. (2008). School science and its controversies; or, whatever happened to scientific literacy? *Public Understanding of Science*, 17(1), 55-72.
- Turoff, M. (1991). Computer-mediated communication requirements for group support. *Journal of Organizational Computing*, 1(1), 85–113.
- Turoff, M., & Hiltz, S. R. (1996). Computer based Delphi processes. . In Adler, M. and Ziglio, E. (Eds.) *Gazing into the Oracle: the Delphi method and its application to social policy and public health*. pp. 56-88.
- Uhl, N. P. (1983). Using the Delphi technique in institutional planning. *New Directions for Institutional Research*, 1983(37), 81-94.
- (UNESCO) & Fensham, P. J. (2008). *Science education policy-making: Eleven emerging issues*. UNESCO. Available online at http://efepereth.wdfiles.com/local--files/science-education/Science_Education_Policy-making.pdf. Retrieved August 15, 2013.
- Urban, W.J. (2010). *More than science and Sputnik: The National Defense Education Act of 1958*. University of Alabama Press. Tuscaloosa, Alabama. 247 pp.
- Urban, W.J., & Wagoner, J. (2008). *American education: A history*. Florence: KY: Routledge.

- Van de Ven, Andrew H, & Delbecq, A. L. (1974). The effectiveness of nominal, Delphi, and interacting group decision making processes. *Academy of Management Journal*, 17(4), 605-621.
- Van Zolingen, S. J., & Klaassen, C. A. (2003). Selection processes in a Delphi study about key qualifications in senior secondary vocational education. *Technological Forecasting and Social Change*, 70(4), 317-340.
- Vernon, W. (2009). The Delphi technique: A review. *International Journal of Therapy & Rehabilitation*, 16(2), 69-76.
- Von der Gracht, H. A. (2012). Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technological Forecasting and Social Change*, 79(8), 1525-1536.
- Wang, Z. (2009). *In Sputnik's shadow: The President's science advisory committee and Cold War America* Rutgers University Press.
- Waddington, D. J., Nentwig, P., & Schanze, S. (Eds.). (2007). *Standards in Science Education: Making it Comparable*. Waxmann Verlag.
- Yeh, Y., Hsu, Y., Wu, H., Hwang, F., & Lin, T. (2013). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the Delphi survey technique. *British Journal of Educational Technology*. Online at: doi: 10.1111/bjet.12078. Retrieved June 25, 2013.
- Yousuf, M. I. (2007a). The Delphi technique. *Essays in Education*, 20, 80-89.
- Yousuf, M. I. (2007b). Using experts' opinions through Delphi technique. *Practical Assessment, Research & Evaluation*, 12(4), 1-8.
- Yore, L.D. (2011). Foundations of scientific, mathematical, and technological literacies – Common themes and theoretical frameworks. In L. D. Yore et al. (Eds.), *Pacific CRYSTAL Centre for Science, Mathematics, and Technology Literacy: Lessons Learned*. pp. 23–44. Sense Publishers.
- Yore, L. D., & Van der Flier-Keller, E. (2011a). Pacific Crystal Centre for Science, Mathematics and Technology Literacy. In L. D. Yore et al. (Eds.), *Pacific*

CRYSTAL Centre for Science, Mathematics, and Technology Literacy: Lessons Learned. pp. 3-22. Sense Publishers.

Yore, L. D., & Van Der Flier-Keller, E. (2011b). Epilogue of Pacific Crystal—Lessons Learned About Science, Mathematics, and Technology Literacy, Teaching and Learning. In *Pacific CRYSTAL Centre for Science, Mathematics, and Technology Literacy: Lessons Learned.* pp. 237-252. Sense Publishers.

Weinrib, J., & Jones, G. A. (2013). *Consultant report securing Australia's future STEM: Country comparisons. Canada's approach to science, technology, engineering and mathematics (STEM): Context, policy, strategy, and programs.* Australian Council of Learned Academies. Retrieved from <http://www.acola.org.au>, August 15, 2013.

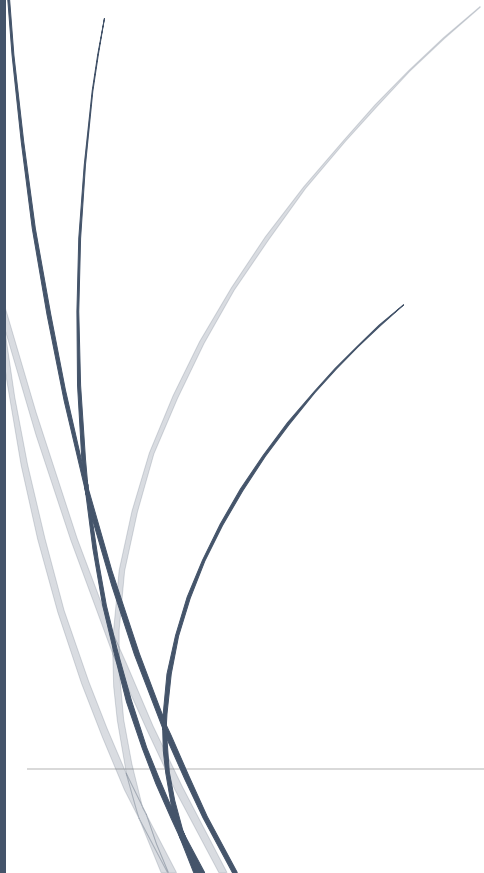
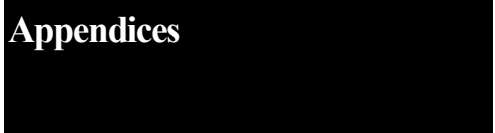
Winchester, I.S. (2006). Large context problems and their application to education: Some contemporary examples. *Interchange*, 37(1/2). pp. 7-17.

Winzenried, A. (1997). Delphi Studies: The value of expert opinion - Bridging the gap - Data to knowledge. In Lighthall, L., & Haycock, K. (1997; Eds.). *Information Rich but Knowledge Poor? Emerging Issues for Schools and Libraries Worldwide.* Research and Professional Papers Presented at the Annual Conference of the International Association of School Librarianship Held in Conjunction with the Association for Teacher-Librarianship in Canada (26th, Vancouver, British Columbia, Canada, July 6-11, 1997).

Woudenberg, F. (1991). An evaluation of Delphi. *Technological Forecasting and Social Change*, 40(2), 131-150. doi: 10.1016/0040-1625(91)90002-W . Accessed September 13, 2013.



Appendices



Appendix ‘A’

Letter of Invitation to the Study



UNIVERSITY
OF MANITOBA

Faculty of Education

December 27, 2013

PARTICIPANT RECRUITMENT LETTER

«Salutation» «First_Name» «Last_Name»
«Position_Title»
«Department»
«Faculty»
«Institution_Name»
«Address_Line_1»
«City» «Province» «Postal_Code»

«GreetingLine»

I am writing to you as a PhD Candidate in the Cohort for Science and Mathematics Education in the Faculty of Education at the University of Manitoba. I am conducting a doctoral research study on Canadian science education for my dissertation. The title of the study is *The Logic of Consensus on Foundations for a Canadian Science Education*. You have been identified by me – the principal investigator - as an expert in science education in Canada and one who may hold personal and professional interest in being a participant in this study. The estimated time commitment is one hour per month over a 4-month project period.

This research study will assemble a council of experts in science education from across Canada in an effort to determine, and provide definition to, the educational system conditions and principal theoretical foundations for the development of a new pan-Canadian consensus on science education. Almost three decades have passed since the Science Council of Canada conducted its *Science Education in Canada* study. We are more than 15 years beyond the Council of Ministers of Education, Canada project which led to the *Common Framework of Science Learning Outcomes K-12*, commonly referred to as the Pan-Canadian Framework. The timing of the study and its potential for informing the future of science education in Canada, therefore, is deemed optimal.

You have been selected as being among the leading experts in the field of science education in Canada, and fit the criteria developed by the principal investigator for the purposes of this study. The methodology chosen for the study is what is known as a *policy Delphi*. This method is particularly suitable in instances where the researcher seeks expert opinion on a complex issue or problem, but with a view to exposing dissent, tensions, and conflict without the expectation of a binding set of resolutions as a final outcome. Consensus is a possible outcome, however, but not one that is deemed forced or artificial. This is why the anonymity of the process and the candor of participants' views are crucial to the success of the Delphi.

Because the Delphi study approach makes use of an iterative series of online questionnaires in several "rounds", the project may take several months to complete. Past experience in similar studies demonstrates that 3 to 4 rounds are usually sufficient to provide participant stability in responses. It is anticipated that each round will require about 1-2 hours of your time over the two-week period that each round will require. The expected total time commitment, therefore, is approximately 6-8 hours over the four-month data collection period. Approximately once per month over the four-month period

December, 2013 to March, 2014, the researcher will provide online availability of the current questionnaire. We use the term “current” because in a Delphi study, the data collected from the previous round informs the structure and items in the questionnaire of the next round.

Participation in this research study is voluntary, and there are no identifiable risks. The time commitment for each round is estimated at one to two hours (dependent upon the depth of treatment you offer), and the survey instrument can be left for a time and resumed at a time that is convenient for you. In addition, each participant will be provided the opportunity to voluntarily agree to participate in one semi-structured interview on issues arising during the Delphi. A total of six (6) participant interviews will be conducted during the study. If selected, the interview will require about 45 minutes in an online, face-to-face environment (e.g., Skype™).

We believe that your participation in this study as a member of the expert council will be a rewarding experience for all involved, and contribute vitality for its success. Therefore, we want you to consider the potential benefits that can derive from your participant status. These could include: appreciating the productive tensions for change in science education in Canada; the sense of having a voice in a study the results of which could hold future significance in our field; the circumstances and timing of the study that make it a unique opportunity and not merely an academic exercise, and; the potential for personal and professional growth and change in values, attitudes, or future contributions. For your participation in this project, you will receive a summary copy of the dissertation and the knowledge of having made an important contribution to the future landscape of activities in science education research, practice, and learning.

If you would like to participate, please send me an email directly to _____ acknowledging your willingness to participate NO LATER than January 6, 2014, and I will promptly send you a Letter of Informed Consent for you to read carefully, sign, and return in a pre-addressed stamped envelope or electronically by e-mail. For purposes of confidentiality, please do not send e-mail correspondence (including “cc” or “bcc”) to the Research Supervisor, Dr. Metz. I hope to begin this study very soon. Should you have any questions or comments regarding this proposed study, feel free to contact me at the locations outlined below. This research has been approved by the Education and Nursing Research Ethics Board of the University of Manitoba under Research Ethics Protocol # E2013:129.

If you have any concerns or comments about this project, you may contact John Murray or Dr. Metz or the Human Ethics Coordinator (HEC) at _____ or _____. Thank-you for your consideration towards participation in this doctoral study.

Sincerely,

Signature of Principal Investigator

Signature of Research Supervisor

Principal Investigator:

Research Supervisor:

John James Murray
PhD Candidate
Faculty of Education
University of Manitoba

Don Metz, PhD (adjunct)
Associate Professor
Faculty of Education
University of Winnipeg

Appendix ‘B’

Letter of Informed Consent to Participate in the Study



UNIVERSITY
OF MANITOBA | Faculty of Education

December 18, 2013

Dear

Thank-you for agreeing to act as a participant in my PhD dissertation study - *The Logic of Consensus on the Foundations for a Canadian Science Education - A Delphi Study*. Yours is an important voice on a rich and broad landscape that will inform the data collection and online discussions that will provide the focus of this research work.

In keeping with the expectations, standards, and protocols of this study, the Education and Nursing Research Ethics Board (ENREB) of the University of Manitoba requires that all participants are in possession of free and informed consent. The form enclosed here is a lengthy one, but I invite you to carefully read through its contents. I draw your attention to the three (3) check-boxes at the end of this form and to the need for a second signature if you also agree to potentially be invited to be interviewed as part of the research. There is no requirement to be interviewed as a component of your participation, but contributing to the online components of the Delphi study is indeed critical to the success of the project.

Please sign both copies of this Informed Consent Form, keep one copy in a safe place for your reference, and return the second copy to me in the self-addressed, stamped envelope provided. You will receive an email reminder about one week after receiving this to provide this signed form as soon as possible. Once all participants have this form on file, the study can begin to unfold.

Again, please accept my gratitude for agreeing to be a part of this doctoral research. I hold every belief that it will be a worthwhile experience that informs the future of Canadian science education and practice.

INFORMED CONSENT FORM

RESEARCH PROJECT TITLE: THE LOGIC OF CONSENSUS ON FOUNDATIONS FOR A CANADIAN SCIENCE EDUCATION – A DELPHI STUDY

Principal Investigator: John James Murray, PhD Candidate
Department of Curriculum, Teaching and Learning
Faculty of Education
University of Manitoba
Winnipeg, Manitoba, CANADA

Research Supervisor: Don Metz, PhD (adjunct)
Associate Professor,
Faculty of Education
University of Winnipeg
Winnipeg, Manitoba, CANADA

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

This research study will assemble a council of experts in science education from across Canada in an effort to determine, and provide definition to, the appropriate educational system conditions and principal theoretical foundations for the development of a new pan-Canadian consensus on science education. Almost three decades have passed since the Science Council of Canada conducted its *Science Education in Canada* study, and we are more than 15 years beyond the Council of Ministers of Education, Canada project which led to the *Common Framework of Science Learning Outcomes K-12*.

You were selected as either being among the leading experts in the field of science education or constitute an important voice in the importance of science education broadly-speaking. Your experiences and influence can be both in Canada and/or internationally, and you fit the criteria developed by the principal investigator for the purposes of this study. The methodology chosen for the study is what is known as a policy Delphi. This method is particularly suitable in instances where the researcher seeks expert opinion on a complex issue or problem, but with a view to exposing dissent, tensions, and conflict without the expectation of a binding set of resolutions as a final outcome. Consensus is a possible outcome, however, but not one that is deemed artificial. This is why the anonymity of the process and the participants' views are crucial to the success of the Delphi.

Assembling a purposeful sampling of science education expertise and selecting an anonymous, online Delphi methodology for this research study provides the following advantages:

- 1) The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis;
- 2) Individuals needed to contribute have no history of direct communication, may represent diverse backgrounds, theoretical commitments, or positions with respect to both experience and expertise;
- 3) Time, vast geography, and cost make face-to-face deliberations infeasible, and;
- 4) Preservation of the heterogeneity of the participants' viewpoints without regard to status, stature, or strength of personality.

The Delphi study approach makes use of an iterative series of questionnaires in several "rounds". Past experience in similar studies demonstrates that 3 to 4 rounds is usually sufficient to provide participant stability in responses. It is anticipated that each

round will require about 1-2 hours of your time over the two-week period that each round will require. The expected total time commitment, therefore, is approximately 6-8 hours over the four-month data collection period. Approximately once per month over the four-month period December, 2013 to

March, 2014, the researcher will provide online availability of the current questionnaire. We use the term “current” because in a Delphi study, the data collected from the previous round informs the structure and items in the next round questionnaire. As stated, the time commitment for each round is estimated at one to two hours (dependent upon the depth of treatment you offer), and the survey instrument can be left for a time and resumed at a time that is convenient for you. Once the online survey/s are completed and submitted electronically to the principal investigator, these data CANNOT be withdrawn. Such data becomes part of the study’s dataset and individual participant data cannot be separated out. IP addresses will not be known to the researcher.

In addition, each participant will be provided the opportunity to voluntarily agree to be selected to participate in one semi-structured interview on issues arising during the Delphi. A total of six (6) participant interviews will be conducted during the study. Two interviews will be conducted at the end of rounds 1, 2, and 3 respectively. If selected, the interview will require about 45 minutes in an online, face-to-face environment (e.g., Skype™) or by telephone with a voice recording. Interviews will be recorded and transcribed by the principal investigator only. Interviewees will be provided a transcript of the interview as a “member check” prior to any use as data informing the study. Individual participant data from interviews can be withdrawn upon request, and such data would then be destroyed in all its forms immediately.

There exist no identifiable risks to participants, either among those who participate in the online survey/s or those consenting to interviews. Your participation in this study for all Delphi rounds is vital for its success. Therefore, we want you to consider the potential benefits that can derive from your participant status. These could include: appreciating the productive tensions for change in science education in Canada; the sense of having a voice in a study the results of which could hold future significance in our field; the circumstances and timing of the study that make it a unique opportunity and not merely an academic exercise, and; the potential for personal and professional growth and change in values, attitudes, or future contributions.

Your information and contributions to the study will remain anonymous to the other participants and will be known only to the principal investigator. My research supervisor – Dr. Don Metz of the Faculty of Education, University of Winnipeg – will have access to raw (hard) survey data and interview transcripts for the purposes of assisting the principal investigator with data management and analysis techniques. Dr. Metz does NOT have access to participant identities (or identifiers) in all instances. Your contact information will be kept private and secure on a password-protected computer housed in a locked office at the home of the researcher.

The survey data will be presented in aggregate form only to the study's participants; your individual responses will never be revealed to anyone but the principal investigator or presented in a manner that could identify you to other participants or the research supervisor, Dr. Metz.

Participation in this study is completely voluntary. You can withdraw at any time without harming your relationship with the researcher, but withdrawal may provide for

the opportunity to provide the researcher with valuable information that contributes anonymously to understanding policy Delphi approaches. There are no known risks or discomforts associated with this research. No debriefing of participants is necessary following data collection phases.

Please be assured that your identity and confidentiality will be maintained at all times. At no time will your name or any closely identifying information be included in any documents generated from this study or in the dissemination of results. If selected for an interview, you may choose a pseudonym for yourself if you like (or one will be chosen for you by the researcher) . All survey data and interview information (both hard copy and/or that which will be stored digitally) is filed and accessed by participant pseudonym to which only the researcher involved in this study will have access. All such data will be stored in a locked drawer in the researcher's home office where only he has access to it. The informed consent form containing your name will not be kept with the survey and interview data but will be stored in a separate locked drawer in the researcher's home office where only he has access to it. These safeguards avoid the possibility of connecting your name to any information that you have given.

Dissemination of the results will include the customary distribution of copies of the dissertation in accordance with: the protocols of the University of Manitoba, Faculty of Graduate Studies; the University of Manitoba Libraries, and; online availability (as full text) through ProQuest™ Dissertations and Theses, LLC. Participants, as part of informed consent, may agree to receive summaries of the research in accordance with established guidelines. As of July, 2014 a summary of the research results will be made

available to participants, and upon request such a summary can be sent via ordinary mail or by email to you. Confidential data will be kept secure until March, 2015 at which time it will be destroyed. Anonymous data will be kept indefinitely. If you wish to receive a copy of the research results summary, please fill in the contact information on this form for this purpose.

If you agree to participate in this study, you can expect to receive further communications at some point in late December, 2013. You are encouraged to ask questions concerning the research before or after agreeing to participate. You will be provided an addressed, stamped envelope in which to return this form. As an alternative, you may scan the signed consent form and e-mail it as a .pdf file to the principal investigator at the address provided on the first page. You will be provided with a duplicate copy of this consent form to keep in a safe place.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at research records to see that the research is being done in a safe and proper way. This research has been approved by the Education and Nursing Research Ethics Board of the University of Manitoba under Protocol #E2013:129. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator (HEC) at _____ or by email at _____.
A copy of this consent form has been given to you to keep for your records and reference.

Insert the letter “X” in this box if you agree to be a member of this expert council panel (sign below).

Insert the letter “X” in this box if you also consent to being contacted again for an interview (provide a second signature below on line containing the words “Consent for Interview”).

I wish to receive a summary of the research results when these are available.

Mailing Address:

or

E-Mail Address

_____@_____

Signature(s) of Participant:

Signature of Research Participant

Date

Signature of Research Participant (If Consenting to Interview)

Date

Signature of Researcher (Principal Investigator):

Signature of Researcher

December 18, 2013

Date

Appendix ‘C’

Delphi Round 1 Questionnaire

Science Education in Canada- Delphi Study Round 1

The Canadian Science Education Landscape to 2030

Thank you for agreeing to participate in this research study. Please read what follows with care. You have been identified as having expertise and understandings related to science education in Canada that can allow for important contributions to be made to the outcomes of this study. Your participation is important to the success of the study. I hope you will endure and find this exercise a fruitful one. The valuable time you spend is gratefully acknowledged.

The following four (4) introductory questions comprise Round 1 of the Delphi research process. These questions are intended to be open-ended, "free-form" responses in order to generate themes that will inform future rounds of questioning in the study. Please read each statement or question carefully and consider a thoughtful response.

NOTE: The text box below each item will expand continuously as you write. It's present size does not constrain your response to the item. You are welcome to cite related literature in your responses as this will provide support for your position and provide a collaborative environment for other participants once they see your anonymous responses in Round 2. Self-citations, as with peer-review manuscripts, are worded as (Author, date) to preserve anonymity. After you complete any portion of this questionnaire, it is advised that you click "Save Page" - do this regularly as you write. If you want to save your

writing at any time to come back later to finish or revise, this option is open to you. Simply click the appropriate button, "Save and Continue Later".

The last 4 items provide the researcher with important demographic data related to the study. You may leave the survey at any time and then return to it again when convenient. Your information will not be lost. You can also change your answers at a later time if this is necessary, but only until you click the "Submit" button. Once you do that, Round 1 is complete for you and your responses are final.

Participant Identification

Please enter the 6-character ID code provided to you by the researcher.(e.g., 1234ST)

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.

Participant Demographics

Thank-you for completing the first part of this Round 1 Delphi questionnaire. The last four items here provide the researcher with important demographic data related to participants in the study.

Question 5

My sex is:

- Female
- Male

Question 6

My current position is best described as working as a(n):(choose only one from drop-down menu)

- Academic Administration (College of Applied Arts/Technology)
- Academic Instructor (College of Applied Arts/Technology)
- Academic (University Emeriti)
- Academic (University; science education faculty)
- Academic (University; science faculty)
- Academic (administration; e.g., dean, chairperson)
- Engineer (P.Eng.)
- Graduate Student

- K-12 Science Teacher (public schools)
- K-12 Science Teacher (private, charter, faith-based)
- Provincial / Territorial Civil Servant
- Non-Governmental Organization
- Science Journalist (or Media)
- Science Teacher Candidate (pre-service)
- Technology, R&D, Industry
- Other (please specify in the space below)

Question 7

This item helps to describe both the location and length of time you have spent in Canadian jurisdiction(s) either working or in formal studies related to science education: (If more than one location over time, choose all that apply beginning with your most recent and working back in time to a maximum of five (5) periods of time). If you select "Other / Outside Canada" for your Location, please include details in the column marked "Other".

You have now COMPLETED the Round 1 Questionnaire of this Delphi Study. Thank-you for your thoughtful responses and your time!

The responses from this questionnaire will inform the construction of the next phase of the study - Round 2. The next round DOES NOT include lengthy responses to open-ended questioning. Please select the appropriate button below. If you select "Submit", this will forward your responses to the researcher and will be FINAL. If you want to stop and return later, select "Save and continue later". If you no longer want to be a participant in this research, select "Discard responses and exit" .

With best regards,

John Murray

Faculty of Education

University of Manitoba

Appendix ‘D’

Delphi Round 2 Questionnaire

Science Education in Canada - Delphi Study Round 2

The Canadian Science Education Landscape to 2030

Thank you for continuing to participate in this research study and for your generous submissions in Round 1. Welcome to Round 2. Please read what follows with care before you begin. Round 1 of the Delphi has produced a number of "themes" which will form the basis of the questionnaire instrument presented here. In Round 2, participants engage in a series of questions which serve to clarify positions on the themes. Most of the items will take the form of rating scales with an opportunity for a brief justification statement, in some instances required.

NOTES: The time required of you to respond will be considerably less than in Round 1. In ALL the rating scales, you can use a particular rating more than once as you go down a list of variables. For example, you may use a "4 - Very Important" as a rating on more than one item in a list. You are NOT forced into ranking items in this questionnaire unless it is a multiple choice question with only a single possible response. The text box below an item, where it may exist, will expand continuously as you write. Its present size does not constrain your response to the item. If you do not feel personally or professionally qualified to answer a particular item, please select "NQ" where this applies.

IMPORTANT: Click "Save Page" BEFORE you click "Next" to move on to the next page. After you complete any portion of this questionnaire, it is advised that you click "Save Page" - do this regularly as you move along. If you want to save your work at

any time in order to come back later to finish or revise, this option is open to you. Simply click the appropriate button, "Save and Continue Later". You may leave the survey at any time and then return to it again when convenient. Your information will not be lost. You can also change your answers at a later time if this is necessary, but only until you click the "Submit" button. Once you do that, Round 2 is complete for you and your responses are final. Notice that you can make use of the "Word" and "PDF" icons to create a personal copy of your responses.

You will have TWO WEEKS to complete Round 2 from the date you received this invitation. A reminder will be sent to you via e-mail 5 and 2 days before the closing date.

Participant Identification

Please enter the 6-character ID code provided to you by the researcher as part of your invitation. (e.g., 1234ST) Then, click "Save Page" then click "Next" .

Global Trends and Science Education

In this section, participants assess the relative importance of the global trends that were identified in Round 1 responses.

Question 1

Please rate the level of importance for each of the global trends listed here in terms of your perceptions of their expected level of influence on formal (school) science

education in the next 20 years. 'Formal' can include post-secondary education environments.⁴⁶

	5- Defining Influence	4 -High Influence	3 -Some Influence	2 -Low Influence	1 -No Influence	NQ
Science, Technology, Engineering & Mathematics (STEM)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Integration of Indigenous Perspectives / Knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Developing Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Science and Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
National/International Student Assessments (e.g., PISA, TIMMS)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
New Learning Technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Relevance of Science Education to Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
National / International Standards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Science Education for Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Re-conceptualizing the Purposes of Science Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Globalization of the International Community	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

⁴⁶ NQ = Not Qualified to Respond

Question 2

Please rate the level of importance for each of the global trends themes listed here in terms of your OPINION of the level of influence each SHOULD HAVE on formal (school) science education in the next 20 years. 'Formal' can include post-secondary education environments. You are encouraged to comment briefly on your selections and opinions in the text box.

	5-Defining Influence	4-High Influence	3-Some Influence	2-Low Influence	1-No Influence	NQ
Science, Technology, Engineering & Mathematics (STEM)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Integration of Indigenous Perspectives / Knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science and Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National/International Student Assessments (e.g., PISA, TIMMS)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New Learning Technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relevance of Science Education to Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National / International Standards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education for Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- Reconceptualizing the Purposes of Science Education
- Globalization of the International Community

Please comment briefly on any of the themes presented in this question in the space below....

Foundations for Science Education

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

Question 3

Please rate the level of importance for each of the foundations of science education listed here in terms your **OPINION** of the level it SHOULD HAVE in formal (school) science education in the next 20 years. You are encouraged to comment briefly on your selections and opinions in the text box.

	5-Primary Importance	4-Very Important	3-Some Importance	2-Not Important	1-No Importance	NQ-Not Qualified to Respond
Science Education for Global Citizenship	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The Nature of Science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science, Technology, Society and the Environment (STSE)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Interacting Natural and Human Global Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientific Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientific Knowledge (i.e., discipline specific content knowledge)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comment briefly in the space below....

Goals of Science Education

In this section, participants assess the goals of science education. For the purposes of this study, 'goals' refers to the larger-scale desired outcomes of a general science education that usually define the overall purposes of conducting science education in the Canadian provinces. In this instance, the goals are confined to what could define the K-12 system of science education; the goals are intended to serve all avenues of adult life.

Question 4

Please rate each of the following goals of science education listed here in terms your opinion of the level of its importance in shaping the future of science education.

You are encouraged to comment briefly on your selections and opinions in the text box.

	5-Primary Importance	4-Very Important	3-Some Importance	2-Not Important	1-No Importance	NQ-Not Qualified to Respond
Citizenship in a Global Technological Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Career-Building for a Technological Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Literacy in Science-Related Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Character Development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Life-Long Learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute to Human Health and Well-Being	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training of Future Scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Develop a Deep Sense of Wonder and Curiosity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pursue Progressively Higher Levels of Study	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sustaining Earth's Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comment briefly in the space below....

Question 5

Imagine that the following description of the relevance of science education was written in the early 1980s: "Tomorrow's citizens and decision-makers are in school today - are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future."

Is this statement about science education, generally-speaking, still relevant as we project out to the year 2030?

- Yes, as is
- No, not relevant
- I would choose to modify it

Question 6

Imagine that the following description of the relevance of science education was written in the early 1990s: "Canadian society is experiencing rapid and fundamental economic, social, and cultural changes that affect the way we live. Canadians are also becoming aware of an increasing global interdependence and the need for a sustainable environment, economy, and society. The emergence of a highly competitive and integrated international economy, rapid technological innovation, and a growing knowledge base will continue to have a profound impact on our lives. Advancements in science and technology play an increasingly significant role in everyday life. Science education, therefore, will be a key element in developing new literacies and in building a strong future for Canada's young people."

Is this statement about science education, generally-speaking, still relevant as we project out to the year 2030?

- Yes, as is
- No, not relevant
- I would choose to modify it

Question 7

Today, I would re-write statements such the ones in Questions 5 & 6 in the following way(s): A response is ENCOURAGED here from all participants who responded "I would choose to modify it" in either of Question 5 or Question 6 above. Prepare a single statement (max. 100 words).

Opportunities and Barriers to a New National Vision for Science Education

In this section, you will be asked to provide an opinion on a number of statements related to potential opportunities and barriers to a national vision for science education. Please note that a brief justification statement for your selection is required for each question.

Question 8

The constitutional provisions in Canada for provincial governments to have control of education provides a favourable situation for science education in Canada.

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly

- NQ-Not Qualified

Please provide a brief justification for your position...

Question 9

The Council of Ministers of Education, Canada (the CMEC) should initiate work on a new Canadian vision for science education.

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

Please provide a brief justification for your position...

Question 10

Deliberate and open consultations with the stakeholders is the most effective way of ensuring that future science education policy in Canada is relevant to the needs of society.

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

Please provide a brief justification for your position...

Question 11

The Canadian provinces should collaborate with the international community on the development of a set of agreed-upon international standards for science education.

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

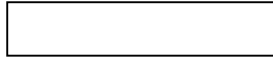
Please provide a brief justification for your position...

Question 12

In your opinion, rate the following contributors to a national vision for science education in Canada with 5 = Significant Opportunity (to achieve a national vision), 3 = Neutral Factor with no net effect, and 1 = Significant Barrier (to achieve a national vision).

	(+2) Significant Opportunity	(+1) Important Opportunity	(0) Neutral Factor	(-1) Important Barrier	(-2) Significant Barrier	NQ-Not Qualified to Respond
Voices of Indigenous Peoples	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inter-Provincial Cooperation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cultural Diversity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Linguistic Diversity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provincial Electoral Cycles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Federal Electoral Cycles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control of Curriculum by Provincial Bureaucracies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Physical Geography	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

You may provide a brief justification for your positions...(optional)



Question 13

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)

	5- Leadership Role	4- Collaborative Role	3- Advisory Role	2- Observer Role	1- No Role
Ministers of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Senior Provincial Staff in Ministries of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education Specialists in Ministries of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Industry Professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Faculties of Education (University)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
College Faculty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Parents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Teachers (K-12)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

You may add one more stakeholder to this list, and identify a role from among the five selections above.

Other Stakeholder (please specify)

Canada and the International Community

Question 14

Please rate the following potential contributors, in terms of their relevance, to a "Canadian approach" to the nature of science education in Canada to the year 2030. Where 5 = Definitely Relevant, 3 = Moderately Relevant, and 1 = Definitely Not Relevant

	5-Definitely Relevant	4-Very Relevant	3-Moderately Relevant	2-Not Relevant	1-Definitely Not Relevant	NQ-Not Qualified to Respond
Canada as a Circumpolar Nation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous Ways of Knowing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Issues of Gender	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Issues of Human Rights	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regional Priorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationships with Trading Partners	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
International Student Collaborations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education for a Democratic Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Career Specializations in the Sciences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- Equity of Opportunity in the Sciences
- Science Education for a Sustainable Future

Please comment briefly on any of the themes presented in this question in the space below.....

Question 15

Please rate the level of your familiarity with, or knowledge about, these types of initiatives or policy positions in science education. Where 5 = Fluent, 3 = Somewhat Familiar, and 1 = No Knowledge at All

	5- Fluent	4-Very Familiar	3-Somewhat Familiar	2-Slightly Familiar	1-No Knowledge At All	NQ-Not Qualified to Respond
Science Council of Canada Study (1984)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science for All Americans (1983)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
AAAS Project 2061 (1985)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National Research Council (NRC) Science Standards (1996)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National Research Council (NRC) Science Standards (2012)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Next Generation Science Standards (2013)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A Provincial Science Curriculum	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A Post-Secondary Science Program Curriculum	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The Pan-Canadian Protocol Science Framework (1997)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
An International Science Curriculum (Outside Canada)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Question 16

Please provide a self-assessment of the depth to which you reviewed the summary of the Round 1 responses to this study

- 5- Reviewed Completely (and more than once)

- 4- Reviewed Completely
- 3- Reviewed Some Sections
- 2- Just a Quick Glance
- 1- Did Not Review

Please go to the next page to finish and log out!

You have now COMPLETED the Round 2 Questionnaire of this Delphi study. Thank-you for your thoughtful responses and your time!

The responses from this questionnaire will inform the construction of the next phase of the study - Round 3. Prior to Round 3, each participant will receive a summary of the Round 2 results. This summary will, for the most part, be statistical.

Please select the appropriate button below. If you select "Submit", this will forward your responses to the researcher and will be FINAL. If you want to stop and return later, select "Save and continue later". If you no longer want to be a participant in this research, select "Discard responses and exit" .

With best regards,

John Murray

University of Manitoba
Faculty of Education

Appendix ‘E’

Delphi Round 3 Questionnaire

Science Education in Canada - Delphi Study Round 3

The Canadian Science Education Landscape to 2030

Thank you for agreeing to continue in this research study, and welcome to Round 3 - the final round with the expert panel. Please read what follows with care before you begin. In Round 2, participants engaged in a series of questions which served to clarify positions on the themes coming forward from Round 1. By now you would have had an opportunity to review summaries and statistics from the Round 2 items. In Round 3, you will respond to many of the SAME items a second time but some have been modified based on expert panel input. As with Round 2, most of the items will take the form of rating scales with opportunity for a brief justification statement.

NOTES:

In Round 3, text comments are optional but are encouraged as these illuminate your thinking. It is recommended that you offer a brief justification statement if you want to solidify your position to other members, are changing your position, or want to respond to comments you have read from the previous round. If you do not feel personally or professionally qualified to answer a particular item, or cannot answer because the item language is too vague, please select "NQ" where this applies.

After you complete any portion of this questionnaire, it is advised that you click "Save Page" - do this regularly as you move along. If you want to save your work at any time in order to come back later to finish or revise, this option is open to you. Simply click the appropriate button, "Save and Continue Later". You may leave the questionnaire

at any time and then return to it again when convenient. Your information will not be lost. You can also change your answers at a later time if this is necessary, but only until you click the "Submit" button. Once you do that, Round 3 is complete for you and your responses are final. Notice that you can make use of the "Word" and "PDF" icons to create a personal copy of your responses. You will see these on the left-hand margin of the final page.

You will have ONE WEEK to complete Round 3 from the date you received this invitation. A reminder will be sent to you via e-mail 5 and 2 days and then once more before the closing of Round 3. Let me say in advance how generous you have been with your time.....this is important to the success of this study.

Participant Identification

Please enter the 6-character ID code provided to you by the researcher as part of your invitation. (e.g., 1234ST) Then, click "Next".

Global Trends and Science Education

In this section, participants assess the relative importance of the global trends that were identified in Round 1 responses.

Question 1

Please rate the level of importance for each of the global trends listed here in terms of your perceptions of their expected level of influence on formal (school) science education in the next 20 years. 'Formal' can include post-secondary education environments.

Round 2 responses are presented below:

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Science, Technology, Engineering & Mathematics (STEM)	3.90	4.00	0.49
Integration of Indigenous Perspectives / Knowledge	3.17	3.00	0.87
Developing Skills for the 21st Century	4.32	5.00	0.72
Science and Education for Sustainability	3.90	4.00	0.62
National/International Student Assessments (e.g., ...TIMMS, PISA)	3.62	4.00	0.72
New Learning Technologies	3.95	4.00	0.63
Relevance of Science Education to Students	3.76	4.00	0.87
National / International Standards	3.54	4.00	1.00
Science Education for Economic Competitiveness	3.56	4.00	1.05
Re-conceptualizing the Purposes of Science Education	3.36	3.00	1.16
Globalization of the International Community	3.49	3.00	0.76

	5- Defining Influence	4-High Influence	3-Some Influence	2-Low Influence	1-No Influence	NQ-Not Qualified to Respond
Science, Technology, Engineering & Mathematics (STEM)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Integration of Indigenous Perspectives / Knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science and Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National/International Student Assessments (e.g., PISA, TIMMS)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

New Learning Technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relevance of Science Education to Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National / International Standards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education for Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reconceptualizing the Purposes of Science Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Globalization of the International Community	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Question 2

Please rate the level of importance for each of the global trends listed here in terms of your opinion of the level of influence each should have on formal (school) science education in the next 20 years. 'Formal' can include post-secondary education environments.

Round 2 responses are presented below:

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Science, Technology, Engineering & Mathematics (STEM)	3.88	4.00	0.89
Integration of Indigenous Perspectives / Knowledge	3.45	4.00	0.89
Developing Skills for the 21st Century	4.31	4.00	0.51
Science and Education for Sustainability	4.36	5.00	0.67
National/International Student Assessments (e.g., ...)	2.90	3.00	0.88
New Learning Technologies	3.88	4.00	0.79
Relevance of Science Education to Students	4.29	4.00	0.61
National / International Standards	3.02	3.00	1.02
Science Education for Economic Competitiveness	3.17	3.00	1.02
Re-conceptualizing the Purposes of Science Education	3.88	4.00	0.99
Globalization of the International Community	3.60	4.00	0.88

You are encouraged to comment briefly on your selections and opinions in the text box.

	5- Defining Influence	4-High Influence	3-Some Influence	2-Low Influence	1-No Influence	NQ-Not Qualified to Respond
Science, Technology, Engineering & Mathematics (STEM)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Integration of Indigenous Perspectives / Knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science and Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National/International Student Assessments (e.g., PISA, TIMMS)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New Learning Technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relevance of Science Education to Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
National / International Standards	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education for Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reconceptualizing the Purposes of Science Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Globalization of the International Community	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comment briefly in the space below.....

Foundations for Science Education

In this section, participants assess the foundations of science education. For the purposes of this study, 'foundations' refers to the large-scale aspects of a general science education that usually help to create frameworks from which science curriculums (curricula) are developed in the Canadian provinces. Alternatively, these foundations could be thought of as the "pillars" upon which science education rests and speaks to its various purposes.

Question 3

Please rate the level of importance for each of the FOUNDATIONS of science education listed here in terms your opinion of the level of its inclusion in formal (school) science education in the next 20 years. Expert panel comments from Round 2 encouraged collapsing "science education for citizenship" and interacting human and global systems" into the foundation area of "science education for sustainability".

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Science Education for Global Citizenship	4.07	4.00	0.70
Science Education for Sustainability	4.43	4.00	0.30
The Nature of Science	4.02	4.00	0.71
Science, Technology, Society and the Environment (STSE)	4.33	4.00	0.47
Interacting Natural and Human Global Systems	4.00	4.00	0.90
Scientific Skills for the 21st Century	4.29	4.00	0.51
Scientific Knowledge (i.e., discipline specific content)	3.79	4.00	0.51

You are encouraged to comment briefly on your selections and opinions in the text box.

	5-Primary Importance	4-Very Important	3-Some Importance	2-Not Important	1-No Importance	NQ-Not Qualified to Respond
Science Education for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The Nature of Science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science, Technology, Society and the Environment (STSE)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientific Skills for the 21st Century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientific Knowledge (e.g., scientific facts, concepts, theories, laws, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comment briefly in the space below.....

Goals of Science Education

In this section, participants assess the GOALS of science education. For the purposes of this study, 'goals' refers to the larger-scale desired outcomes of a general science education that usually define the overall purposes of conducting science education in the Canadian provinces. In this instance, the goals are confined to what defines the K-12 system of science education as it then acts to serve all avenues of adult life.

Question 4

Please rate each of the following goals of science education listed here in terms of your opinion of the level of its importance in shaping the future of science education. You are encouraged to comment briefly on your selections and opinions in the text box.

Round 2 responses are presented below:

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Citizenship in a Global Technological Society	3.93	4.00	0.75
Career-building for a Technological Society	3.55	4.00	0.69
Economic Competitiveness	3.19	3.00	0.79
Literacy in Science-Related Issues	4.45	4.50	0.35
Personal Character Development	3.19	3.00	0.65
Life-Long Learning	4.07	4.00	0.51
Contribute to Human Health and Well-Being	4.17	4.00	0.63
Training of Future Scientists	3.40	3.00	0.54
Develop a Deep Sense of Wonder and Curiosity	4.24	4.00	0.53
Pursue Progressively Higher Levels of Study	3.10	3.00	0.77
Sustaining Earth's Systems	4.24	4.00	0.58

	5-Primary Importance	4-Very Important	3-Some Importance	2-Not Important	1-No Importance	NQ-Not Qualified to Respond
Citizenship in a Global Technological Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Career-Building in a Technological Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Economic Competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Literacy in Science-Related Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Character Development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Life-Long Learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribute to Human Health and Well-Being	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training of Future Scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Develop a Deep Sense of Wonder and Curiosity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pursue Progressively Higher Levels of Study	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sustaining Earth' Systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comment briefly in the space below.....

Opportunities and Barriers to a New National Vision for Science Education

In this section, you will be asked to provide an opinion on a number of statements related to potential opportunities and barriers to a national vision for science education. Please note that a brief justification statement for your selection can be made for each item.

Question 5

The constitutional provisions in Canada for provincial governments to have control of education provides the most favourable situation for science education in Canada. Round 2 responses are presented below:

Mean (Avg.)	Median(50th percentile)	Variance (S.D.) ²
3.05	3.00	1.35

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

You may provide a brief justification for your position...

Question 6

The Council of Ministers of Education, Canada (the CMEC) should initiate work on a new Canadian vision for science education.

The responses from Round 2 are presented below:

Mean (Avg.)	Median(50th percentile)	Variance(S.D.) ²
3.82	4.00	1.47

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

You may provide a brief justification for your position...

Question 7

Deliberate and open consultations with a broad spectrum of stakeholders in science education offers the most effective way of constructing future science education policy in Canada that contains real commitments to realizing its recommendations.

Responses from Round 2 are presented below:

Mean (Avg.)	Median (50th percentile)	Variance(S.D.) ²
-------------	--------------------------	-----------------------------

4.05

4.00

0.90

- 5-Agree Strongly
- 4-Agree
- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

You may provide a brief justification for your position...

Question 8

The Canadian provinces should collaborate with the international community on the development of a set of agreed-upon international standards for science education.

The responses from Round 2 are presented below:

Mean (Avg.)	Median (50th percentile)	Variance (S.D.) ²
-------------	--------------------------	------------------------------

3.38

3.50

1.27

- 5-Agree Strongly
- 4-Agree

- 3-Neutral
- 2-Disagree
- 1-Disagree Strongly
- NQ-Not Qualified

You may provide a brief justification for your position...

Question 9

In your opinion, rate the following contributors to a national vision for science education in Canada with +2 = Significant Opportunity (to achieve a national vision), 0 = Neutral Factor with no net effect, and -2 = Significant Barrier (to achieve a national vision).

Round 2 responses are presented below:

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Voices of Indigenous Peoples	1.05	1.00	0.42
Inter-Provincial Cooperation	0.62	1.00	1.40
Cultural Diversity	0.82	1.00	0.92
Linguistic Diversity	0.31	0.00	0.74
Provincial Electoral Cycles	-0.70	-1.00	0.99
Federal Electoral Cycles	-0.67	0.00	0.91
Control of Curriculum by Provincial Ministries of Education	-0.64	-1.00	1.50
Physical Geography	0.38	0.00	0.77

	+2 Significant Opportunity	+1 Important Opportunity	0 Neutral Factor	-1 Important Barrier	-2 Significant Barrier	NQ-Not Qualified to Respond
Voices of Indigenous Peoples	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inter-Provincial Cooperation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cultural Diversity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Linguistic Diversity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provincial Electoral Cycles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Federal Electoral Cycles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Control of Curriculum by Provincial Ministries of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Physical Geography	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

You may provide a brief justification for your positions...

Question 10

In your OPINION, please rate each of the education stakeholder groups listed below 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).

Round 2 comments from the expert panel now provide some additional stakeholders.

Round 2 responses are presented below:

	Mean (Avg.)	Median (50 th percentile)	Variance (S.D.) ²
Ministers of Education	3.30	3.00	1.29
Senior Provincial Civil Servants	2.83	3.00	1.17
Science Education Civil Servants	3.88	4.00	0.98
Industry Professionals	3.42	3.50	0.76

Faculties of Education (University)	4.08	4.00	0.48
College Faculty	3.75	4.00	0.45
Parents	2.95	3.00	0.72
Students	3.33	3.00	1.05
Science Teachers (K-12)	4.28	4.00	0.31
Academic Scientists	3.73	4.00	0.51

	5- Leadership Role	4- Collaborative Role	3- Advisory Role	2- Observer Role	1- No Role
Ministers of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Senior Provincial Officials in Ministries of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Education Specialists in Ministries of Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Industry Professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Faculties of Education (University)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
College Faculty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Parents of Students	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Students (K-12)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science Teachers (K-12)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Academic Scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aboriginal Elders and Knowledge Keepers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Concerned Citizens (conflict- free)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Non-Academic Scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Science Communicators (e.g., media, writers)

Labour Organisations

A Provincial Roundtable
Comprising All the Above
Stakeholders

You may provide a brief justification for your positions...

Question 11

Please rate the following potential contributors, in terms of their relevance, to a "Canadian approach" to the nature of science education in Canada to the year 2030. Where 5 = Definitely Relevant, 3 = Moderately Relevant, and 1 = Definitely Not Relevant.

Round 2 responses are presented below:

	Mean (Avg.)	Median (50th percentile)	Variance (S.D.)²
Canada as a Circumpolar Nation	3.86	4.00	0.84
Indigenous Ways of Knowing	3.66	4.00	0.99
Issues of Gender	3.24	3.00	0.89
Issues of Human Rights	3.44	3.00	0.88
Regional Priorities	3.51	3.00	0.89
Relationships with Trading Partners	2.59	3.00	1.08
International Student Collaborations	3.50	4.00	0.80
Science Education for a Democratic Society	4.08	4.00	0.91
Career Specializations in the Sciences	3.58	3.50	0.63
Equity of Opportunity in the Sciences	3.47	3.50	0.90
Science Education for a Sustainable Future	4.50	5.00	0.58

In response to expert panel ratings in Round 2, some of the categories have been eliminated for the Round 3 ratings.

	5- Definitely Relevant	4-Very Relevant	3- Moderately Relevant	2-Not Relevant	1-Definitely Not Relevant	NQ-Not Qualified to Respond
Canada as a Circumpolar Nation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Indigenous Ways of Knowing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Issues of Human Rights	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regional Priorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
International Student Collaborations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science in a Democratic Society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Career Specializations in the Sciences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Equity of Opportunity in the Sciences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Follow-up Questions

Question 12

Please provide a self-assessment of the depth to which you reviewed the summaries of the expert panel responses from Round 2 prior to this questionnaire.

- Reviewed Detailed Version with Participant Comments in Depth
- Reviewed Short Statistical Version in Depth
- Reviewed Some Sections of at Least One Summary
- Just a Quick Glance at Short Statistical Summary
- Did Not Review Any Summaries

Question 13

The professional position that had the greatest influence on informing my responses in this study is best described as a(n):(choose only one from drop-down menu)

- Academic Administration (College of Applied Arts/Technology)
- Academic Instructor (College of Applied Arts/Technology)
- Academic (University Emeriti)
- Academic (University; science education faculty)
- Academic (University; science faculty)
- Academic (administration; e.g., dean, chairperson)
- Engineer (e.g., P.Eng.)
- Graduate Student
- K-12 Science Teacher (public schools)
- K-12 Science Teacher (private, charter, faith-based)

... 2 additional choices hidden ...

- Science Teacher Candidate (pre-service)
- Technology, R&D, Industry
- Public Understanding of Science
- Historian of Science
- Public Policy Researcher

- Education Charitable Organisation
- Science Outreach in the Community
- Educational Researcher
- Government Scientist
- None of the Above

Question 14

In this question, you will indicate the orientation you have, personally, to one of two visions for science education. Please do this by selecting where you are in the continuum scale below. Selecting a '4' indicates an uncompromising commitment to that particular vision for science education.

VISION I: A focus on the products of science such as models, laws, theories and processes such as hypothesizing and experimenting; in this vision, the goals for school science are based on the knowledge and skills sets which enable students to approach and think about situations as a professional scientist would.

VISION II: A focus on examining situations in which science has a role such as decision-making about socio-scientific issues; in this vision, the goals of school science are based on the knowledge and skills sets that enable students to approach and think about situations as a citizen well-informed about science would.

4 3 2 1 0 1 2 3 4



Question 14a (alternate)

In this optional version of Question 14, you will indicate the orientation you have, personally, to one of two visions for science education. Please do this by dragging the slider feature to position yourself where you are in the continuum scale below (the values you see as you move the slider are considered absolute values not +/- values) . Selecting the far end (left or right) indicates an uncompromising commitment to that particular vision for science education. Somewhere near the centre indicates that your orientation is somewhat of a shared commitment to the two visions.

VISION I: A focus on the products of science such as models, laws, theories and processes such as hypothesizing and experimenting; in this vision, the goals for school science are based on the knowledge and skills sets which enable students to approach and think about situations as a professional scientist would.

VISION II: A focus on examining situations in which science has a role such as decision-making about socio-scientific issues; in this vision, the goals of school science are based on the knowledge and skills sets that enable students to approach and think about situations as a citizen well-informed about science would.



Your may provide comments or clarifications about your selections in 14 and 14a here:

Question 15

Are you currently directly involved with the teaching of science in some capacity?

- Yes
- No

Question 16

For this study, five (5) distinct levels of teaching are defined. At which level does MOST of your current science teaching take place?

- Early Years (usually K-6)
- Middle Years (usually grades 7-9; secondaire 1-3 en QC)
- Senior Years (usually grades 10-12; secondaire 4-5 en QC)
- Post-Secondary (college, CEGEP, university, adult learners, etc.)
- My science teaching is outside the formal education system
- I have never been a teacher of science in any type of setting

Question 17

Please indicate your assessment of the importance of each of the following objectives for the level of science teaching which you identified in Question 16 above. Please do not respond to these items if you selected "I have never been a teacher of

science in any type of setting" in Question 16 above. If this applies to you, "Save Page" and click "Next".

	Essential	Very Important	Moderate importance	Low Importance	No Importance
Understanding scientific facts, concepts, theories, laws, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing personal/social skills (e.g., cooperation, communication, responsibility)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relating the learning of science directly to career opportunities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing the necessary skills (e.g., numeracy, literacy) to understand science-related reading material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the nature of, and processes involved in, engineering or technology activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fostering attitudes usually associated with the scientific endeavor (e.g., curiosity, creativity, perseverance, skepticism, argument from evidence)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appreciating the role of history and philosophy of science informing practice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the practical applications of science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing the skills and processes of investigation (e.g., observing, classifying, conducting an inquiry, asking testable questions)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the relevance of science for students who are not aligned with Euro-centric traditions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Relating scientific explanations to students' personal conceptions of the world	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the way in which scientific knowledge is generated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing an awareness of the practices of science in Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the role and significance of science in the world of the 21st century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

You may comment on these objectives here:

Note: At this point, there was a “jump to page” in the event the participant answered “no” to Question #15.

Question 16

For this study, five (5) distinct environments for the teaching of science are defined - 4 formal and 1 non-formal. In which of the following environments did MOST of your science teaching take place?

- Early Years (usually K-6)
- Middle Years (usually grades 7-9; secondaire 1-3 en QC)
- Senior Years (usually grades 10-12; secondaire 4-5 en QC)
- Post-Secondary (college, CEGEP, university, adult learners, etc.)
- My science teaching was outside the formal education system
- I have never been a teacher of science in any type of setting

Question 17

Please indicate your assessment of the importance of each of the following objectives for the level of science teaching which you identified in Question 16 above. Please do not respond to these items if you selected "I have never been a teacher of science in any type of setting" in Question 16 above. If this applies to you, "Save Page" and click "Next".

	Essential	Very Important	Moderate importance	Low Importance	No Importance
Understanding scientific facts, concepts, theories, laws, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing personal/social skills (e.g., cooperation, communication, responsibility)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relating the learning of science directly to career opportunities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing the necessary skills (e.g., numeracy, literacy) to understand science-related reading material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the nature of, and processes involved in, engineering or technology activity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fostering attitudes usually associated with the scientific endeavor (e.g., curiosity, creativity, perseverance, skepticism, argument from evidence)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appreciating the role of history and philosophy of science informing practice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the practical applications of science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing the skills and processes of investigation (e.g., observing, classifying, conducting an inquiry, asking testable questions)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the relevance of science for students who not are aligned with Euro-centric traditions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relating scientific explanations to students' personal conceptions of the world	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the way in which scientific knowledge is generated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing an awareness of the practices of science in Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Understanding the role and significance of science in the world of the 21st century	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

You may comment on these objectives here:

Please go to the next page to finish and log out!

You have now COMPLETED the Round 3 questionnaire of this Delphi study. Thank-you so much for your thoughtful responses and your time. The data collection phase is now completed.

You have been a willing and gracious participant in a very important study looking at the future of science education in Canada and its relationship to the world. The responses from this questionnaire will inform the next phases of the study - data analysis, summaries of results and recommendations. You will receive a summary of the Round 3 data and certain individuals will be contacted for a brief interview to clarify their positions further. Please select the appropriate button below. If you select "Submit", this will forward your responses to the researcher and will be FINAL. Then, you will be directed to an important exit page. If you want to stop and return later, select "Save and continue later". If you no longer want to be a participant in this research, select "Discard responses and exit" .

With best regards,

John Murray

Faculty of Education

University of Manitoba

Appendix ‘F’

Interview Questions Protocol

INTERVIEW QUESTIONS PROTOCOL

Following the application of the Delphi Rounds 1, 2, and 3 questionnaires at least two (2) volunteer participants – one from COHORT 1 and one from COHORT 2 - will be addressing certain questions that intend to open up new policy considerations through Critical Incident Technique. ‘Critical incidents’ are defined here as retrospective experiences or moments in time that an individual considers as turning points, crucial events, or otherwise singular opportunities gained (or lost) in this case as related to science education in Canada. As there will be interviewees who will freely respond to deeper questioning without prompts, and others who will be more comfortable with some guiding prompts throughout the process, the researcher will look to be cued in this regard and make adjustments to the line of questioning with discretion. Here are the interview questions:

1. Please talk to me about how you view your past contributions to research, teaching practices, and the development or implementation of science curriculum. *This question is intended to be open-ended, allowing the interviewee lots of space for conversation, gaining comfort with the interviewer, and seeing themselves in a researcher-practitioner relationship.*
2. Can you describe for me, in terms of where your current vantage point is in science education in Canada right now, your vision of what the future of science education in Canada could (or should) look like?
3. From your perspective, what system conditions – local school district, national, or international – initiate science curriculum change in Canada over time? What effects, if any, have these “system conditions” had on the curriculum development process?
4. You indicated in the Round 1 survey instrument that you had direct involvement with the development of the CMEC *Common Framework of Science Learning Outcomes* in the mid-1990s. Describe the nature of that experience with specific reference to the following: the manner in which your expertise was utilized in the framework development; the degree of satisfaction you had with the process; the important successes that can be identified, and; the omissions or missed opportunities from your perspective. *Or, if interviewee did not participate in the development of the CMEC 1997 pan-Canadian Science Framework development, and indicated this in the survey component, go to (5).*
5. Please respond to the following statement and question: “In Canada, curriculum policy-making is always inevitably a political process. Therefore, one must seek a consensus among the stakeholders who are “on the outside” (e.g., academics, industry partners, etc.) but also manage to collaborate effectively with the “insiders” (e.g., teachers, provincial bureaucrats, etc.)” In your view, how might these two groups of stakeholders participate in future science curriculum development in Canada?
6. The history of Canadian science education has been described in terms of “changing emphases”. Where should the emphases be for the next 15 or 20 years in Canadian science education?

7. If you could envision what, for you, would be the most desirable set of foundations for the next period of reform in Canadian science education, what might these foundations of curriculum look like?
8. In your view, is there the possibility of a uniquely *Canadian approach* to science curriculum policy that appeals directly to the context of Canadian society, its demographic and geographic diversity, and its position internationally?
9. If you were given the opportunity to help develop, at a national level, a new process for determining a Canadian consensus on science education, what might such a process involve? (e.g., who are the architects of the process?; what role(s) are granted to stakeholders?; what research model best informs the process?)
10. There is a movement in science education circles to establish *international science standards*. Does the establishment of international common core standards for science education present for you a threat or an opportunity (or both)?
11. Might there be a “science curriculum for sustainability”, or stated another way, a “curriculum of sustainability sciences” that - from your vantage point – could constitute the core direction for the future of Canadian science education? If so, what would its foundations and/or principles look like if you could help to create it? If not sustainability, is there an alternative central purpose for science education in Canada?

Thank-you for your participation in the interview process.

If questions arise about this interview protocol, please contact me by e-mail at: (removed)