EXECUTIVE SUMMARY

Science Culture: Where Canada Stands

Expert Panel on the State
of Canada's Science Culture

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

SCIENCE CULTURE: WHERE CANADA STANDS

Expert Panel on the State of Canada's Science Culture

THE COUNCIL OF CANADIAN ACADEMIES
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The Council of Canadian Academies

Science Advice in the Public Interest

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Expert Panel on the State of Canada's Science Culture

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The Council also recognizes the important contribution to this assessment of Ian Hacking, C.C., FRSC, University Professor Emeritus in Philosophy at the University of Toronto.

Message from the Chair

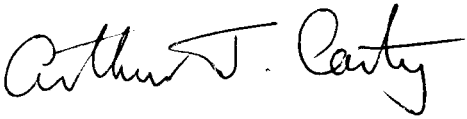
Over 50 years ago, English physicist and novelist C.P. Snow gave his famous "Two Cultures" lecture in which he bemoaned the chasm between the sciences and society. If Snow were alive today he would be astonished at the changes that have taken place since then, principally driven by science, technology, and their application to society. In 1959 he could not have imagined the dawn of the information technology revolution, or the impact of biotechnology, modern medicine, and new materials on society. The pace of change, the mobility of people and resources, the speed and ease of communication, the rapid rise of emerging nations in a global knowledge-based economy, climate warming, and environmental stress — all of these developments underline that there has never been a time in history when science and technology have had a greater impact on citizens. Some understanding of science is now an integral part of being an informed citizen and almost every decision governments make has a scientific component.

Have we succeeded in bridging the chasm between the sciences and society that Snow referred to or has the gulf widened? That question is difficult to answer, but much evidence suggests that the gulf remains. It is abundantly clear that we must continue to strive for a society that is generally knowledgeable and literate about science and places a high value on science and its applications.

Over the course of the past year and a half, I was privileged to chair a panel charged with assessing the current state of Canada's science culture. The results of this investigation, presented here, are both encouraging and sometimes sobering. Canadians do benefit from a strong science culture in many respects and have much to be proud of. However, causes for concern remain and there is room for improvement.

On behalf of the Panel, I would like to extend my thanks to the Canada Science and Technology Museums Corporation, Industry Canada, and Natural Resources Canada for sponsoring this inquiry, and to the Council of Canadian Academies for expertly supporting the Panel throughout its deliberations. I would also like to thank the 10 external reviewers who took the time to review and critique an earlier draft of the Panel's report.

This assessment is a contribution to ongoing conversations about science, society, and culture in Canada. I look forward to continuing to participate in these conversations, and hope this Panel's study plays a useful part in informing future discussion and debate.



Arthur Carty, O.C., FRSC, FCAE
Chair, Expert Panel on the State of Canada's Science Culture

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Many individuals and organizations assisted the Expert Panel over the course of its deliberations, sharing information about Canada's science culture landscape that would have been difficult to obtain otherwise. The Panel would like to thank the following individuals in particular for their assistance: Penny Park at the Science Media Centre of Canada; Bonnie Schmidt at Let's Talk Science; Chantal Barriault at Science North; Lesley Lewis at the Ontario Science Centre; Kathryn O'Hara at Carleton University; Tracy Ross and Amber Didow with the Canadian Association of Science Centres; Derek Jansen and colleagues at EKOS Research Associates Inc.; Geoff Rayner Canham at Memorial University; Peter Calamai; and Paul Dufour.

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Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations.

The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the authoring Panel and the Council.

The Council wishes to thank the following individuals for their review of this report:

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The report review procedure was monitored on behalf of the Council's Board of Governors and Scientific Advisory Committee by **Gregory S. Kealey, FRSC**, Professor, Department of History, University of New Brunswick. The role of the report review monitor is to ensure that the Panel gives full and fair consideration to the submissions of the report reviewers. The Board of Governors of the Council authorizes public release of an expert panel report only after the report review monitor confirms that the Council's report review requirements have been satisfied. The Council thanks Dr. Kealey for his diligent contribution as report review monitor.

Elizabeth Dowdeswell, O.C.
President and CEO, Council of Canadian Academies

Executive Summary

Science is a fundamental part of Canadian culture and society, affecting nearly every aspect of individual and social life. It is a driving force in the economy, catalyzing innovation and creating new goods, services, and industries. It has led to improvements in Canadians' physical health and well-being. It has made possible new forms of communication and learning, and changed how Canadians interact and relate to one another. It also provides opportunities for leisure and entertainment as Canadians visit science centres, pursue science-related hobbies, or tune in to such television programs as "The Nature of Things" or "Découverte". Science is also a systematic means of discovery and exploration that enriches our individual and collective understanding of the world and universe around us.

Most of the impacts of science on society are broadly welcomed as science has improved the quality of life in modern, industrialized societies in numerous ways. However, the applications of science and technology can also be a source of debate and controversy. Some individuals in Canada and other industrialized countries harbour reservations about science, worrying about its potentially disruptive influences or that the pace of scientific and technological change is "too fast" for society to cope with. Science also features prominently in public debates about politically divisive issues such as climate change, genetically modified foods, nuclear power, the use of embryonic stem cells, or the risks associated with biotechnology and nanotechnology. Concerns are raised that too few citizens have an understanding of science sufficient to grasp these issues and therefore lack the ability to participate in public debates in an informed manner. As a result, society's relationship with science can at times seem strained, characterized by a deep dependence on the one hand and by apathy or apprehension on the other.

THE CHARGE TO THE PANEL

In 2012 the Canada Science and Technology Museums Corporation, Industry Canada, and Natural Resources Canada asked the Council of Canadian Academies (the Council) to investigate the state of Canada's science culture. This request was driven by both the recognition of the role that science culture plays in maintaining Canada's demonstrated strengths in science and technology, and

by concerns that Canada potentially lags behind other countries in terms of how deeply science is embedded in Canadian culture. The Council was tasked with forming an expert panel to address the following questions:

What is the state of Canada's science culture?

- *What is the state of knowledge regarding the impacts of having a strong science culture?*
- *What are the indicators of a strong science culture? How does Canada compare with other countries against these indicators? What is the relationship between output measures and major outcome measures?*
- *What factors (e.g., cultural, economic, age, gender) influence interest in science, particularly among youth?*
- *What are the critical components of the informal system that supports science culture (roles of players, activities, tools and programs run by science museums, science centres, academic and not-for-profit organizations and the private sector)? What strengths and weaknesses exist in Canada's system?*
- *What are the effective practices that support science culture in Canada and in key competitor countries?*

To address this charge, the Council convened a 14-member multidisciplinary panel of experts (the Panel). The Panel drew on three principal lines of research in exploring its charge: (i) a review of the existing literature on science culture in Canada and abroad, (ii) a new public survey of science culture in Canada commissioned by the Panel, and (iii) an inventory and analysis of the organizations and programs that support and promote science culture in Canada. The Panel's findings represent its collective judgment based on its review of the best available evidence.

ASSESSING CANADA'S SCIENCE CULTURE

As understood by the Panel, a society has a strong science culture when it embraces discovery and supports the use of scientific knowledge and methodology. Such a culture encourages the education and training of a highly skilled workforce and the development of an innovative knowledge-based economy. The concept of science culture is multidimensional, incorporating a number of distinct dimensions pertaining to how individuals and society relate to science and technology. The national context also influences how science culture develops and is expressed. The Panel's analysis of science culture in Canada focused on four key dimensions:

- public *attitudes* towards science and technology;
- public *engagement* in science;
- public science *knowledge*; and
- science and technology *skills* in the population.

Established indicators from surveys and other data sources can be used to assess these four dimensions with a reasonable degree of rigour and accuracy. International comparisons and trends over time can place these data in context and aid in their interpretation.

The Panel also surveyed the system of social and institutional support for science culture in Canada, reviewing the network of organizations, programs, and initiatives that provide opportunities for informal science learning and engagement (i.e., science learning and engagement occurring outside of the school system).

Although the Panel was charged to assess Canada's *science* culture rather than its *science and technology* culture, distinguishing between the two is often impractical as the public frequently does not differentiate between them. As a result, both terms are used in this report depending on the context.

THE CURRENT STATE OF SCIENCE CULTURE IN CANADA

The main findings from the Panel's analysis are summarized here. Table 1 presents data for selected indicators. The rankings should be regarded as an approximate indicator of Canada's international standing as data may be from different years and not all differences in rank are statistically significant.

Public Attitudes Towards Science and Technology

Canadians have positive attitudes towards science and technology and low levels of reservations about science compared with citizens of other countries.

Like citizens of other industrialized countries Canadians hold both positive and negative attitudes about science and technology, though positive attitudes predominate. Approximately three-quarters of Canadians agree with statements such as "all things considered, the world is better off because of science and technology" and "science and technology are making our lives healthier, easier and more comfortable." On an index based on standard survey questions assessing beliefs about the promise of science and technology, Canada ranks 9th out of 17 industrialized countries. Relative to citizens of other countries, however, few Canadians express beliefs such as "it is not important for me to know about science in my daily life" or "we depend too much on science and not enough on faith." On an index based on standard questions assessing public reservations about science, Canada ranks 1st among the same 17 countries, indicating low levels of concern about any potentially disruptive impacts of science and technology. Public reservations about science in Canada have also declined on average since 1989.

Table 1

Summary Table of Selected Science Culture Indicators

Indicator	% or Score	Rank
Public Attitudes Towards Science and Technology		
Public views about the "promise" of science (index)[a]	7.3/10	9th out of 17 countries
Public reservations about science (index)[b]	3.0/10	1st out of 17 countries
% of pop. agreeing that even if it brings no immediate benefits, scientific research that adds to knowledge should be supported by government	76%	12th out of 35 countries
Public Science Engagement		
% of pop. that reports being very interested or moderately interested in new scientific discoveries and technological developments	93%	1st out of 33 countries
% of pop. that has visited a science and technology museum at least once in previous year	32%	2nd out of 39 countries
% of pop. that regularly or occasionally signs petitions or joins street demonstrations on matters of nuclear power, biotechnology, or the environment	23%	3rd out of 33 countries
% of pop. that regularly or occasionally attends public meetings or debates about science and technology	14%	5th out of 33 countries
% of pop. that regularly or occasionally participates in activities of a non-governmental organization dealing with science/technology-related issues	14%	1st out of 33 countries
% of pop. that regularly or occasionally donates to fundraising campaigns for medical research	63%	7th out of 33 countries

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Indicator	% or Score	Rank
Public Science Knowledge		
Estimated % of pop. that demonstrates a basic level of scientific literacy[c]	42%	1st out of 35 countries
Average score on OECD PISA 2012 science test[d]	525	10th out of 65 countries
Average score on OECD PISA 2012 math test[d]	518	13th out of 65 countries
Science and Technology Skills		
% of pop. aged 25–64 with tertiary education	51%	1st among OECD countries
% of first university degrees in science and engineering fields	20%	19th out of 29 countries
% of first university degrees in science fields awarded to women	49%	4th out of 28 countries
% of first university degrees in engineering awarded to women	23%	19th out of 28 countries
% of all doctoral degrees in science and engineering fields	54%	4th out of 37 countries
% of total employment in science and technology occupations	30%	22nd out of 37 countries

The table presents data for a selection of science culture indicators examined by the Panel. Canada's performance is ranked relative to other countries for which comparative data are accessible for each indicator. In cases of ties, both countries receive the same rank. [a]Index that combines responses to three science attitudes questions whereby a higher score represents more positive attitudes about the promise of science. [b]Index that combines responses to three science attitudes questions, with a lower score representing fewer reservations about science (/10). [c]Percentage of population that is identified as "civically scientifically literate" using Jon Miller's methodology, i.e., having the level of science knowledge necessary to comprehend the Science section of *The New York Times* (Miller, 2012). This rank should be interpreted with caution as the year of data collection varies by country. [d]Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) test scores are scaled so that the mean score is approximately 500 and the standard deviation is 100.

Canadians express above-average levels of support for public funding of scientific research, and a strong majority of Canadians view science and technology as important in pursuing a range of social objectives such as environmental protection and improving Canada's economic prospects. However, since 2004 Canadians have become slightly more skeptical about the ability of science and technology to achieve these objectives.

Public Engagement in Science

Canadians exhibit a high level of engagement with science and technology relative to citizens of other countries.

Ninety-three per cent of Canadians report being either very or moderately interested in new scientific discoveries and technological developments. Canada ranks 1st out of 33 countries on this measure. Canadians are also more likely to visit a science and technology museum than citizens of any other country except Sweden. Nearly one-third of Canadians report having visited such an institution at least once in the past year, and this share has increased over the past two decades. Canadians also show high levels of participation in scientific activities and organizations in other ways, such as donating money to medical research, taking part in activities of non-governmental organizations (NGOs) related to science or technology, and signing petitions or joining street demonstrations on nuclear power, biotechnology, or the environment.

Public Science Knowledge

Established, survey-based measures suggest that Canadians' level of science knowledge is on a par with or above citizens of other countries for which data are available.

Public surveys in the United States and Europe have used standard factual and open-ended questions to assess public science knowledge for several decades. Based on data from the Panel's survey, Canadians have a relatively high level of understanding of core scientific constructs and methods. Moreover, their level of science knowledge has increased since 1989. Canada ranks first on a science literacy index among countries for which data are available. Around 42% of the population in Canada, compared with 35% in Sweden and 29% in the United States, exhibits a sufficient level of science knowledge to grasp basic scientific concepts and understand general media coverage of scientific and technological issues. This ranking should be interpreted with caution, however, as Canadian data are more recent and science literacy has been improving over time in most countries. The survey data are consistent with findings from student assessments such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study), which show that on average Canadian students excel in achievements in science and mathematics compared with students in most other countries. Canada's PISA scores in science and mathematics, however, have declined since 2006, raising the concern that Canada is failing to keep pace with other leading countries.

Science and Technology Skills

Canada's performance on indicators of science and technology skills development is variable compared with other OECD countries.

While Canada ranks first among OECD countries in overall post-secondary educational attainment (the portion of the population aged 25–64 with college and university degrees), only 20% of first university degrees in Canada are in the sciences and engineering. Canada ranks 19th out of 29 countries on this measure, well behind leaders like Korea (32%) and Germany (30%). The proportion of students graduating with engineering degrees in Canada is particularly low. Despite this ranking, the sciences' share of first degrees in Canada has been relatively stable over the past decade while declining in the majority of developed economies. Immigration also plays an important role in determining the availability of these skills. Over half (51%) of individuals holding science, technology, engineering, and mathematics degrees in Canada are immigrants. Although Canada has a relatively low level of doctoral graduation, a large share of Canada's doctoral degrees are granted in the sciences and engineering. Similar patterns are evident in OECD occupational statistics. The share of Canada's workforce employed in areas relating to science and technology is near the OECD average, and particularly low in the manufacturing sector.

INSTITUTIONAL AND SOCIAL SUPPORT FOR SCIENCE CULTURE IN CANADA

Many types of organizations contribute to the advancement of science culture in Canada, including formal science education providers, informal science learning institutions like museums and science centres, a growing array of electronic and print science learning resources, and friends and family. The formal and informal science learning systems are linked, and experiences in formal science education are major drivers of national science culture. In this respect, Canada's science education system at the primary and secondary levels strongly contributes to Canadians' comparatively high levels of scientific knowledge and engagement.

The science culture support system is also dynamic. New organizations, programs, and initiatives are continually created while older ones are discontinued. A 2011 inventory of science culture and communication initiatives in Canada identified more than 700 such programs or organizations. These include over 400 initiatives related to museums, science centres, zoos, or aquariums; 64 NGOs or associations; 49 educational initiatives; 60 government policies and programs; 27 media

programs; and a variety of other organizations and programs. These organizations fulfil a range of different functional roles within the system of informal science interventions in Canada.

Given a lack of internationally comparable data, there is no scientifically rigorous way of evaluating the strengths and weaknesses of Canada's system of informal science engagement and learning interventions relative to that of other countries. However, a number of informed observations can be made based on the available evidence:

- The success of Canada's network of science centres and museums is reflected in their strong international reputations and relatively high numbers of annual visitors.
- Several long-standing, iconic Canadian science media programs (in French and English) contribute to informal science learning.
- General science coverage in the English-language Canadian press is limited by few dedicated science reporters, a function of the decline of print media in general. However, television and radio continue to have well-recognized and established science programming. Canadians also increasingly rely on the internet for information on science and technology topics.
- Private industry and research institutes also support science culture in Canada, and research organizations play an active role in some forms of public outreach and engagement.
- Federal, provincial, and municipal governments in Canada support science culture through a range of programs, though the federal government has not been as active as some of its peers in articulating a national vision or strategy for science culture. Some provincial governments, most notably Quebec and Ontario, have been more active in supporting public science outreach and engagement.
- Concerns about how federally employed scientists are allowed to communicate with the media have been widely reported in the Canadian and international media in recent years, raising questions about the extent to which current policies limit opportunities for public communication and engagement.
- Canada also lacks a dedicated funding program for research on informal science learning like the one provided by the National Science Foundation in the United States. The lack of such a program limits resources for informal science learning initiatives in Canada and curtails the development of knowledge about the effectiveness of existing programs and institutions.

CULTIVATING A STRONG SCIENCE CULTURE

The Panel's research on cultivating a strong science culture identified relevant interventions under five broad themes. The quality of the evidence available to evaluate these interventions is variable. While science education and learning have been the subject of extensive academic research over the years, other types of practices reviewed by the Panel have received less study and could benefit from more research.

Supporting Lifelong Science Learning: Exposure to science in the formal school system is a critical determinant of the level of science knowledge in the adult population. At the same time, individuals spend a small portion of their lives in formal school settings, and will continue to encounter new needs for scientific information throughout their lifetimes. Effective strategies for promoting science knowledge therefore recognize the importance of formal educational settings in providing a foundation of knowledge and skills, while, at the same time, offering a variety of channels through which the adult population can continue to seek out information on science.

Making Science Inclusive: Tailoring science learning and engagement opportunities to the social and cultural contexts of groups traditionally underrepresented in the sciences can make science more inclusive. Such strategies will vary depending on the group. Young women are more likely to develop interest and pursue science learning when they can see the social relevance of the subject matter and when given the opportunity to engage with scientists and mentors. For Aboriginal populations, recognizing and incorporating aspects of traditional knowledge into curricula and instruction can be effective.

Adapting to New Technologies: All organizations involved in activities related to science culture need to adapt to a rapidly changing technological environment. New technologies are threatening the viability of traditional models of instruction and communication and changing the ways in which people seek information on scientific topics. New technologies can be used to augment science education and engagement strategies in many ways. Internet-based resources may allow learners to tailor learning to their own style and interests. Technology can also enhance a variety of science outreach activities, and offer new modes of public engagement (e.g., citizen science) and communication (e.g., social media and blogs).

Enhancing Science Communication and Engagement: Scientists who are encouraged to communicate with the public and equipped with the tools to engage successfully can build support, knowledge, and interest across the population. A careful framing of science communication will factor in the social and cultural context of the audience, and how messages will resonate with diverse groups. Engaging the public in certain areas of science decision-making can also make science more relevant to society and increase science knowledge of participants. Other approaches to facilitating public engagement in science include acknowledging debate and controversy and linking science with other aspects of culture such as the arts.

Providing National or Regional Leadership: Governments can play a role in supporting science culture by articulating a vision for science culture that provides a framework for action across organizations and a foundation for coordination. Governments can also promote the value of science, incorporate science into policy-making, strengthen science learning through the formal education system, provide leadership, and share information.

THE IMPACTS OF A STRONG SCIENCE CULTURE

Many claims have been advanced about the impacts of a strong science culture. Such claims are often plausible given the extent to which science and technology feature in most aspects of individual and social life. However, there is limited empirical evidence to substantiate these claims, and in some cases that evidence points to more complexity in the way these impacts are manifested than is typically acknowledged. Much of this evidence suggests that, while a stronger science culture may contribute to a range of personal or social benefits, it is not always in itself sufficient to ensure the realization of those benefits. The Panel explored these impacts in relation to four domains: impacts on individuals, impacts on democracy and public policy, impacts on the economy, and impacts on scientific research.

Impacts on Individuals: Improving scientific knowledge can help individuals better differentiate between fact and opinion, make more informed consumer choices, and better evaluate personal and public health risks. However, it is not a guarantee of more effective individual decision-making, which can be affected by many other factors, including underlying cultural values and common cognitive biases and heuristics (i.e., innate or ingrained decision-making rules). Different forms of scientific knowledge (i.e., knowledge of scientific processes versus scientific facts) are also not necessarily of equal value or relevance in informing individual decisions in daily life.

Impacts on Democracy and Public Policy: Science plays a defining role in many policy debates faced by current governments. Some level of knowledge of science is therefore critical to enabling informed public participation in policy issues involving science and technology. However, increasing knowledge does not ensure higher levels of participation or more effective policy-making. The types of public engagement opportunities available to citizens and the institutional mechanisms for incorporating science advice into policy-making also determine the nature of any impacts on policy outcomes.

Impacts on the Economy: As understood by the Panel, a strong science culture is one that supports the development of advanced science and technology skills in the population. A strong science culture can therefore reasonably be expected to bolster an economy's capacity for innovation through increasing the supply of these skills. However, the relationships between the supply of skills and economic outcomes are complex, and there are many other determinants of both innovation performance and aggregate economic outcomes. As a result, a greater supply of science and technology skills will not necessarily lead to improved economic outcomes in all contexts.

Impacts on Scientific Research: Increased public engagement in science can benefit research through greater public support of and participation in different kinds of research activity such as clinical trials or provision of medical samples or health data. Online platforms are also creating novel opportunities for public engagement in scientific research.

FINAL REFLECTIONS

Much of the evidence reviewed by the Panel speaks to the relative strength of Canada's science culture. Canadians exhibit high levels of science knowledge and of engagement in scientific activities relative to their peers abroad. However, it remains an open question whether Canada's science culture is sufficiently robust for a technologically advanced, democratic society in the 21st century. Despite Canada's high international standing, more than half of Canadians lack the understanding of basic scientific concepts needed to make sense of major public debates on scientific issues. Based on the Panel's research, 54% of Canadians cannot describe what it means to study something scientifically, which compromises the ability of Canadians to meaningfully engage in public discussions involving science. Similarly, the 72% of Canadians unable to describe a molecule will struggle to make sense of public debates on the safety of nanotechnology, and the 49% of Canadians with little understanding of DNA cannot fully comprehend the possibilities or risks associated with new genetic

research and technologies. Persistent gender disparities with respect to science knowledge, interest, and attitudes also indicate that Canada's science culture is not equally well established across all segments of the population.

There are many rationales for cultivating a strong science culture. One of the simplest is that doing so helps foster a fuller, richer experience of science itself. As a systematic means of discovery and exploration, science enables individuals to more fully understand and appreciate the world around them. A strong science culture is also one that celebrates the experience of science in this light, and works to ensure that all individuals (and all segments of society) have opportunities to share in the wonder and excitement of science. Canadians are fortunate to have many such opportunities, but science and society are both constantly evolving, and developing a stronger science culture in Canada — one with a nuanced understanding and appreciation of the myriad ways in which science is deeply ingrained in society — remains a work in progress.