Consultant Report
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STEM: Country Comparisons

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Canada's Approach to Science, Technology, Engineering and Mathematics (STEM): Context, Policy, Strategy, and Programs

Dr Julian Weinrib
Professor Glen A. Jones
University of Toronto

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Canada's Approach to Science, Technology, Engineering and Mathematics (STEM): Context, Policy, Strategy, and Programs

The objective of this report is to collate, synthesize and analyze a variety of STEM-related educational programs, outputs and outcomes in the context of the Canadian post-secondary education sector. We begin by providing a brief introduction to the structure and political economy of PSE in Canada in order to foreground the overview and provide much needed context for the particular set of circumstances that have shaped STEM-related policies and programs in Canada, particularly over the past 10 years.

Overview of the Canadian System

Postsecondary education in Canada

While the federal government plays a major role in funding university research, supporting a national student loans program, and operating a range of programs and initiatives that have important implications for Canadian higher education, it is the ten provinces and three territories that have legislative authority over all levels of education. Under Canada's constitution, education is the responsibility of the provinces; there is no national ministry of education or higher education and no national higher education policy or legislation. As such, there are considerable variations in funding mechanisms and governance structures by province.

However, despite the provincial variations, the influence of the federal government remains strong in areas related to the national economic well-being and quality of life, such as access to postsecondary education and research and development. The importance of the federal government's role in these areas was reinforced during the 1990s when the government of Canada made major reductions in provincial transfers to the provinces as a function of deficit reduction, and then, at the turn of the century, made major reinvestments in higher education under the guise of a national strategy for innovation through research and development (Shanahan & Jones, 2007).

The decentralized nature of Canada's university 'system' is replicated at the provincial level, with universities historically enjoying high levels of autonomy. In terms of the governance and autonomy of Canada's public postsecondary institutions, almost all Canadian universities have been created as private, not-for-profit corporations operating under unique provincial legislation and regulation. While there is a very small private university sector, the vast majority of universities are considered public in that they receive operating grants from the respective provincial governments and are considered part of a broader public sector of institutions.

In addition to universities, each Canadian province has created one or more other types of postsecondary institution that are frequently termed 'community colleges' (or simply 'colleges') though it is important to note that the role, mission and structure of these institutions varies by province. These colleges deliver some combination of short-cycle vocational programming, trades programs, and intensive specialized technical and/or career programs. Colleges in some provinces offer pre-university or university-transfer programs. In the majority of provinces and territories, colleges are much more tightly controlled by government than universities, and have been seen as a more flexible means for governments to address regional economic needs and demands (Jones, 2006).

Key PSE indicators

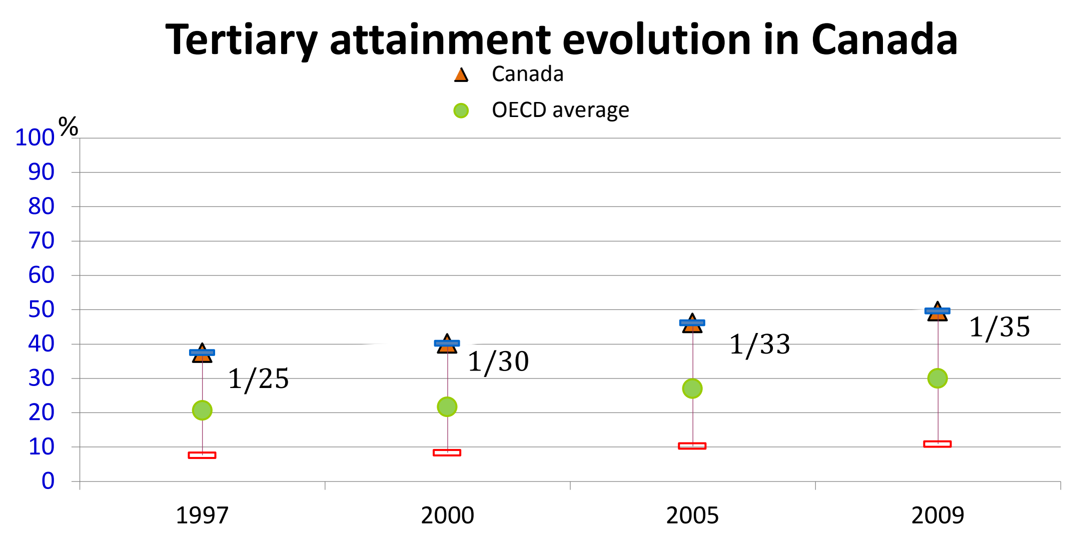
Postsecondary attainment

Using the OECD *Education at a Glance* educational program levels, definitions and indicators (OECD, 2012a, 26-27), access to and attainment of tertiary education (defined as both college and university completion) between 1997 and 2010 amongst 25-64 year-olds in Canada expanded at a similar, if slightly lower rate, than OECD comparator states (ibid, 37-38): the proportion of individuals who had completed their education at one of the tertiary levels rose from 37% to 51% in Canada, with OECD averages rising from 21% to 30% over the same time period, and Australia's average rose from 24% to 38% (ibid, 37). Amongst the thirty-five countries with available data for analysis by the OECD, including an array of non-OECD nations, Canada's tertiary attainment rate placed it first in 2010, compared to Australia's 8th place attainment rate.

One caveat of Canada's growth when compared to international counterparts is that between 1997 and 2009 the average annual growth rate for tertiary attainment in Canada (2.4%) was 1.4% lower than the OECD average (3.7%), including 1% lower than Australia (3.3%) (OECD, 2011, 40; OECD, 2012a, 37). However, as evidenced by chart A below, Canada has maintained the highest tertiary attainment rate since 1997.

One of the defining features of the Canadian PSE sector is the relative balance between attainment of university and advanced research credentials (ISCED type-5A) and non-university credentials (ISCED type-5B); in 2010, 24% of Canadians aged 25-64 had completed tertiary type-B programs, the highest rate in the OECD, compared to an average of 10%, including 11% in Australia (OECD, 2012a, 34). For type-5A attainment, Canada's rate was 26%, placing it 8th in the OECD compared to a 21% average, including 26% in Australia (ibid, 34).

Chart A – Tertiary attainment rates, Canada vs. OECD, 1997-2009



Source: OECD, 2012a, Table A1.4
Rank /no. of countries label is placed below right for country values.

It is important to note that in conforming national post-secondary institution categories to the ISCED parameters there has been some attainment rate inflation due to Statistics Canada's data management system and the particular case of Quebec's provincial post-secondary system. Statistics Canada, the body responsible for gathering data on tertiary attainment, does not distinguish between some adult education and occupational preparation programs in Canadian community colleges. Because the latter would normally be categorized as non-tertiary post-secondary education for other OECD countries, Canada's ISCED 5B attainment rates are inflated in cross-country comparisons.

With regard to Quebec, its education system incorporates an additional unique layer between the traditional secondary and tertiary levels, the *Cégep* system. Whereas all other provinces support 12 years of schooling before tertiary enrollment, Quebec differs by supporting only 11 years followed by an additional 2-year pre-university stream or a 2-year technical training stream. Both streams contain a general education component and a more specialized preparatory component. As all *Cégep* students are counted towards ISCED 5B enrollment, there is an artificial inflation of this attainment in the Quebec case, which impacts the overall Canadian narrative to some degree.

As a part of the general attainment scores, the OECD also tracks age and gender attainment rates. With regard to gender, Canada boasts the highest tertiary attainment rates for women amongst all OECD countries, at 56% compared to an OECD average of 32% (Statistics Canada, 2012, 105). For the 25-34 year-olds, Canada's tertiary attainment rate stands at 56% as of 2010, compared to an OECD average of 37% and an Australian indicator of 44%, placing Canada second of thirty-seven surveyed countries and Australia seventh (OECD, 2012a, 36).

Labour market outcomes and employment rates

As can be expected from research in the general literature on the correlation between educational attainment and employment, the most recent OECD data confirms that higher levels of educational attainment consistently result in both higher employment rates and higher earning premiums for those attaining tertiary credentials (degrees, diplomas and certificates) in Canada (Statistics Canada, 2012, 16). In the Canadian context, this general phenomenon has been reinforced by an ongoing major shift from a manufacturing-based to a knowledge-based economy in many parts of the country, particularly in the most populous province, Ontario. A 10-year labour market forecasting report produced by Human Resources and Social Development Canada indicated that between 2008 and 2017 the employment share of occupations requiring a university education would rise from 12.1% to 17.8% (HRSDC, 2008).

In 2010, the employment rates for Canadian tertiary graduates was 81.3%, slightly lower than the OECD average (83.1%) and the Australian rate (84%) (OECD, 2012a, 132-133). In terms of overall employment rates for tertiary graduates in 2010, Canada's 82% rate places 19th amongst 35 surveyed countries (ibid, 133). However, an interesting note is that the proportion of university-educated workers in low-skilled jobs increased from 35% in 1997 to 39% in 2007, suggesting an oversupply of university graduates, at least in certain fields (OECD, 2012b, 21). These numbers may be skewed by the development of natural resources, such as the oil sands, where better wage prospects exist in sectors requiring lower skill levels. However, even in lower skilled occupations, university graduates tend to earn higher wages than those with less education (HRSDC, 2008).

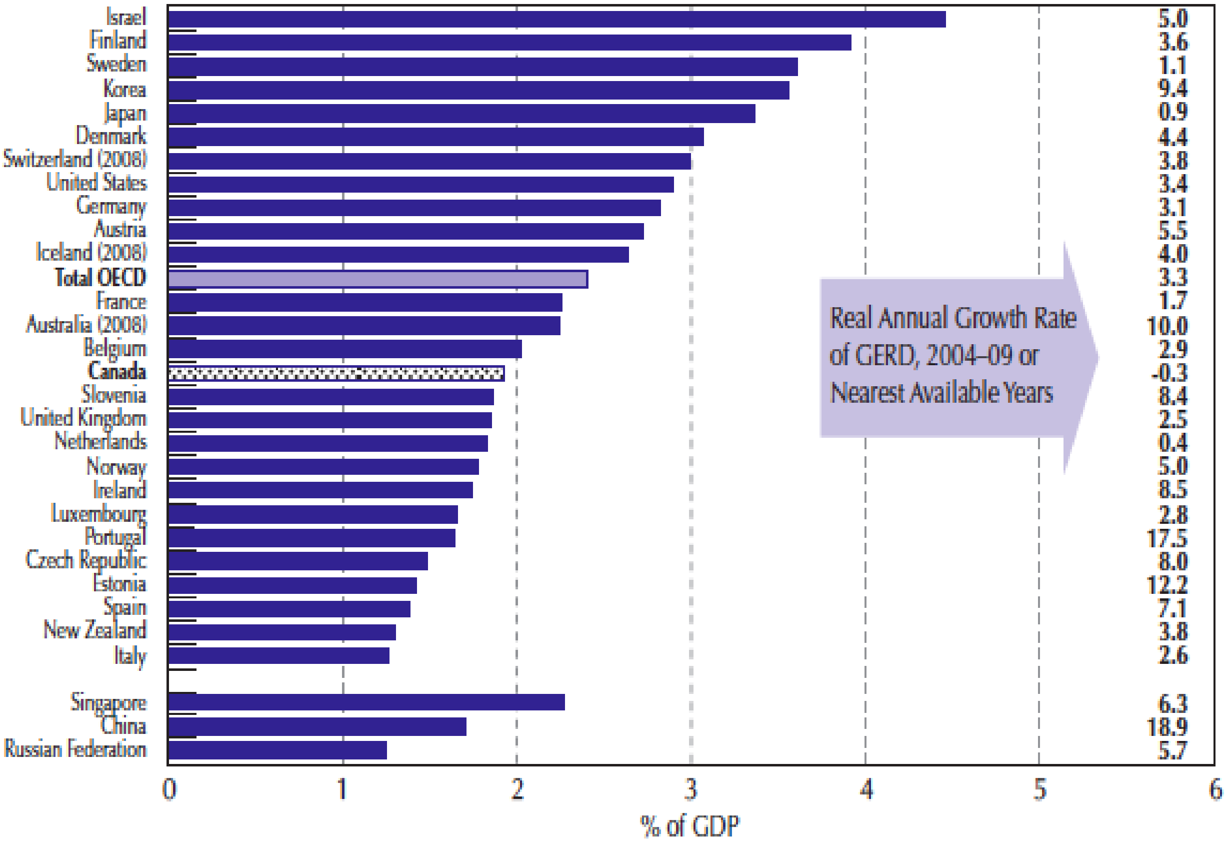
Using the latest available data, in 2009 the impact that the level of educational attainment had on earnings from employment (before tax) was significant in Canada, but below the OECD average; on the aggregate, Canadians with a university or advanced credential (ISCED 5A/6) earned 38% more than graduates of upper secondary or postsecondary non-tertiary programs, significantly below the 55% OECD average (OECD, 2012a, 140). However, when this number is broken down between ISCED 5A and 5B graduates, it is clear that relatively low earnings premiums for college graduates are depressing the overall tertiary rate. The 2009 earning premium rates for 25-64 year-olds for 5B graduates was only 11%, whereas for 5A graduates it was close to 90% greater than upper secondary or postsecondary non-tertiary graduates (OECD, 2012b, 20).

After taking into account the costs of training (including the opportunity cost of foregone earnings), the annual private returns to tertiary education are calculated to be 11.9% for men and 11.1% for women, slightly below the OECD averages of 12.4% and 11.5%, respectively (OECD, 2011a).

Research and development indicators

Gross Domestic Expenditure on Research and Development (GERD)

GERD represents the total R&D performed in a country and the ratio of GERD over GDP is a standard indicator of a country's overall R&D effort. In the most current available data (2009), Canada's GERD-GDP stood at 1.9%, ranking it 15th among OECD countries. Perhaps more important to the static ranking is that over the previous five years (2004-2009) Canada's real annual growth rate of GERD was in decline at 0.3%, and was the only OECD country to be experiencing a negative growth rate (See Table X). GERD can be broken down into two primary sub-sectors of expenditure on research and development - higher education and business – both of which will be examined below.



Source: OECD, 2011b, Main Science and Technology Indicators 2011/12

The first major category of analysis is higher education research and development expenditures (HERD), a measure of the level of research conducted by public higher education and research institutions and personnel. In 2009, Canada's HERD-GDP ratio was the fifth highest among OECD countries at just over 0.7%, compared to an OECD average of 0.4% (Industry Canada, 2012). Approximately 38% of Canada's R&D was performed by the higher education sector. The real annual growth rate of Canada's HERD-GDP ratio between 2004 and 2009 was 1.8%, the third lowest amongst OECD countries.

The second major category of R&D expenditure is business enterprise expenditures on research and development (BERD), which encompasses all forms of industrial R&D. In 2009, Canada's BERD ratio was 1.0, down from its peak of 1.3 in 2001, and 52% of R&D was performed by the business sector (OECD, 2011c). Canada continues to trail behind the OECD average (1.6), placing it 19th amongst OECD countries. Canada trails significantly behind the leading countries, such as Israel (3.4), and Sweden, Japan and Korea (2.5) (ibid, 2012). As with GERD-GDP, Canada's BERD-GDP between 2004 and 2009 also declined at an annual growth rate of -2.1%, making it one of only three countries (the other two being Netherlands and Luxembourg) with a negative rate.

The third major category of R&D support is government, which can funnel its expenditures through a number of secondary avenues (higher education, business, foreign, or intramural) or produce primary research and development activities. In Canada, Government expenditures account for 20.6% of total R&D in 2009, with the largest share being directed to higher education institutions. Canada's government expenditure on R&D (GOVERD) as a percentage of GDP was 1.9% for 2009, placing it well below the OECD average of 2.7. The real annual growth rate between 2004 and 2009 was 2.2%, ranking Canada 15th of 23 OECD countries (ibid, 2012).

Number of researchers in Canada

As evidenced by the data in Table 1, while Canada's total number of researchers in raw numbers is quite low compared to comparator countries, when calculated on a per capita basis (per million inhabitants) Canada places 5th amongst OECD countries (CCA, 2012a, 123). One caveat to this is that Canada's growth rate lags significantly behind some of the traditional research powerhouses and emerging economies such as China and Brazil.

Table 1 – International comparison of total domestic researchers, researchers per million population and growth rates, 2004-2008

Country	**Researchers**		**Researchers / million inhabitants (2008)**	**Growth rate (%)**
	2004	**2008**		
Norway	21,163	26,505	5,504	25.7
Japan	653,747	656,676	5,190	0.4
Sweden	48,784	46,719	5,018	-4.2
United States	1,384,536	1,412,639	4,673	12.8
Canada	**130,383**	**142,948**	**4,335**	**9.6**
Australia	81,192	91,617	4,259	12.8
United Kingdom	228,926	235,373	3,794	2.8
Germany	270,215	311,500	3,780	15.3
France	202,377	229,130	3,689	13.2
China	926,252	1,592,420	1,199	71.9
Brazil	98,341	133,266	696	35.5

Source: Canadian Council of Academies, 2012a, 123

Canadian scientific output

With less than 0.5 per cent of the world's population, Canada produces 4.1% of the world's scientific papers and nearly 5% of the world's most frequently cited papers. Between 2005-2010, Canada produced 59% more papers than in 1999-2004, and was the only G7 country with an increase above the world average (CCA, 2012b, xii). When measured by Average Relative Citations (ARC), Canada is ranked sixth in the world, and on a field-by-field basis, Canada's ARC rankings place it among the five leading countries in the world in 7 of 22 fields of research, and among the 10 leading countries in another 14 (ibid, xii). Despite Canada's strong publication record, Canadian researchers only account for 1.5% of the world's patents (ibid, xiii).

1.1 Attitudes towards STEM, and the priority given to STEM, in: families, the community/media, government, educational institutions, employers and professional bodies

As previously articulated, the decentralized nature of the Canadian post-secondary education sector, as a facet of Canadian federalism, has led to a number of idiosyncrasies in the public policy formation processes and program development at the federal level (Fisher et al., 2006; Shanahan & Jones, 2007; Fisher et al., 2009). The constitutionally mandated diffusion of power and control between the federal and provincial/territorial governments has significantly impacted the extent to which national leaders and policy-makers can directly influence two areas of particular concern in relation to enhancing STEM education and uptake within the labour market; research and development (R&D) policy and programs, and labour force development (Fisher et al, 2009; Metcalfe & Fenwick, 2009; Sa, 2010).

While the federal government lacks direct control over educational policies in the country's provinces and territories, it has produced a limited number of policy papers aimed at influencing national and provincial narratives and programming in science, technology and innovation-related sectors in order to support the country's economic development and the evolution of Canadian society in line with global norms. As in other parts of the world, dating back to the late 1980s and emerging more forcefully in the early 21st century, R&D, particularly in STEM-related fields of study, became recognized as an integral component in the economic development of jurisdictions. As a result, and given the limited mechanisms possessed by the federal government to influence provincial educational policies, successive federal governments in Canada have worked towards bridging the university-industry divide in order to leverage public funds in support of private investment in R&D. This push has also led to a series of strategic investments in human capital development, specifically in high-skill STEM-related areas, as a means for drawing post-secondary institutions and their researchers, both faculty and students, into more productive relationships with the market, both Canadian and global.

Again, as there is no federal ministry of education in Canada, and since each province and territory has jurisdiction over its own educational portfolio and curricula, efforts by the federal government to augment the country's STEM-related human capital and research and development systems, including the country's standing within the global knowledge economy, have been implemented through a variety of arms-length organizations, ministries and funding mechanisms; Industry Canada, the Tri-Council research granting agencies, and the Canadian Foundation for Innovation, to name a few that will be examined in this report.

The following section provides an overview of the limited policy and discussion papers that have been put forward by both governmental and non-governmental agencies and organizations, with a specific focus on how key Canadian stakeholders conceptualize and position the connection between STEM fields and the country's economic productivity and well-being. Reports are presented in order to provide a general summary of the document in relation to STEM-related human capital development and to highlight key indicators and metrics chosen by both government and non-government bodies as measures of the country's strength in STEM-related productivity. This section introduces some of the major STEM-related programs that have been instigated as a result of the following reports. The cornerstone programs will be investigated in further detail in section 1.6 of this report.

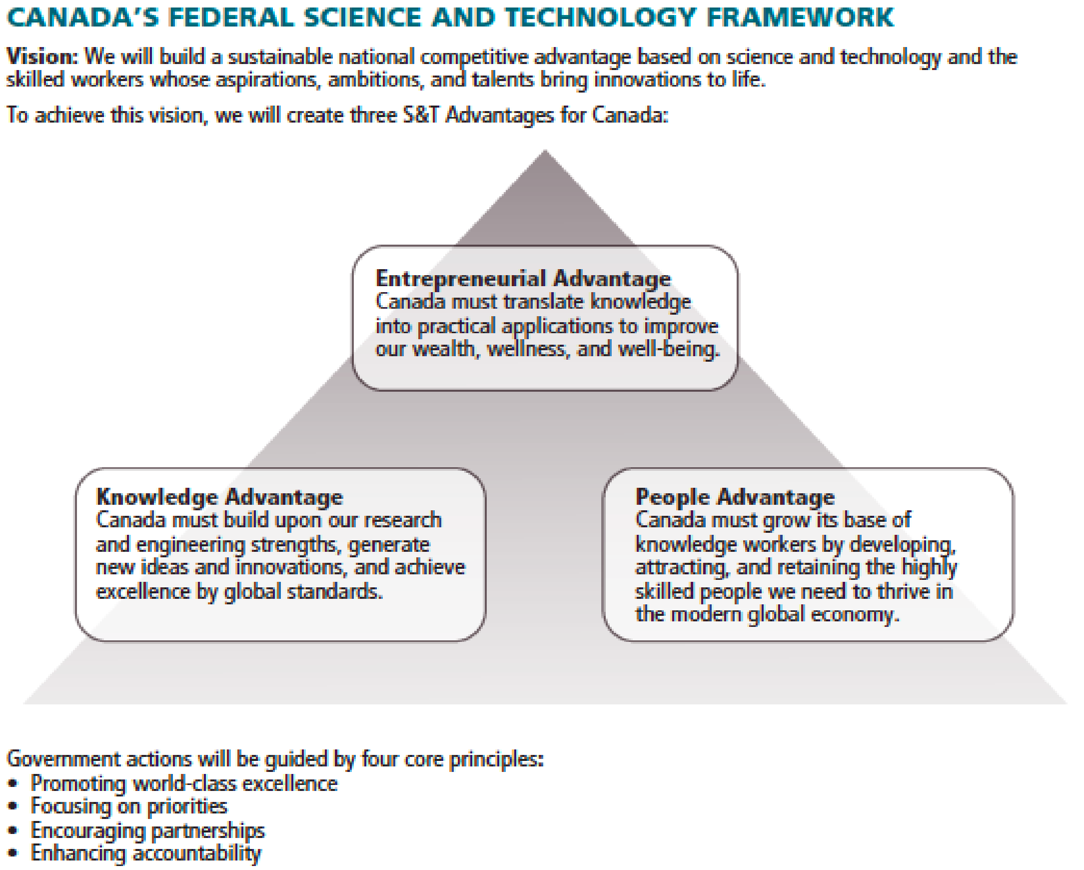
1.1.1 Government reports

2007 *Mobilizing Science and Technology to Canada’s Advantage* Report

In 2006, the Prime Minister of Canada, Stephen Harper, announced his governments’ intention to develop a new strategy for science and technology research and researchers in Canada. The primary catalysts for this development were lagging business-related investments in research and development and the increased emphasis on knowledge-based economic activity in the global economy, including a decline in Canadian manufacturing-based economic activities. With regard to the former, while Canada led the world in terms of the Higher Education Research and Development (HERD)-GDP ratio, it consistently trailed comparator countries in the Gross Expenditure on Research and Development (GERD)-GDP ratio, primarily due to extremely low Business Enterprise Expenditure on Research and Development (BERD).

The consultation process initiated by the Prime Minister culminated in a strategy paper that advocated for increased engagement with the Canadian S&T sector in order to develop three national advantages, as outlined in Figure 1: an ‘Entrepreneurial Advantage’, a ‘Knowledge Advantage’ and a ‘People Advantage’ (Industry Canada, 2007). The major output of the paper from the standpoint of federal S&T strategy was a drive to encourage greater private-sector investment in S&T, the perceived need to focus on select S&T priority areas, a recognition that the country’s already high standing in publicly performed R&D required sustaining, general considerations for alternative management arrangements for non-regulatory federal R&D labs, the consolidation of an assortment of advisory councils into a single ‘Science, Technology and Innovation Council’, and the need to create additional funding opportunities for S&T researchers and students (Fast, 2007, 6-7).

Figure 1



CANADA'S FEDERAL SCIENCE AND TECHNOLOGY FRAMEWORK

Vision: We will build a sustainable national competitive advantage based on science and technology and the skilled workers whose aspirations, ambitions, and talents bring innovations to life.

To achieve this vision, we will create three S&T Advantages for Canada:

Entrepreneurial Advantage
Canada must translate knowledge into practical applications to improve our wealth, wellness, and well-being.

Knowledge Advantage
Canada must build upon our research and engineering strengths, generate new ideas and innovations, and achieve excellence by global standards.

People Advantage
Canada must grow its base of knowledge workers by developing, attracting, and retaining the highly skilled people we need to thrive in the modern global economy.

Government actions will be guided by four core principles:
- Promoting world-class excellence
- Focusing on priorities
- Encouraging partnerships
- Enhancing accountability

Reproduced from Industry Canada, 2007

The initiatives that were developed and implemented immediately following the publication of the strategy paper significantly altered the Canadian research landscape. Some examples are (see Section 1.5.1 for a more comprehensive overview):

1. A series of new Networks of Centres of Excellence were created to support stronger ties between post-secondary institutions and industry, including stronger incentives for the commercialization of academic research;
2. Significant reductions in a variety of tax rates in order to spur private sector investment in R&D and the creation of new businesses, including the Scientific Research and Experimental credit;
3. Federal research granting programs were given four priority areas (environmental S&T, resources and energy, health and related life sciences, and information and communication technologies), which quickly became mapped onto the funding agendas of federal granting agencies, particularly the Natural Science and Engineering Research Council;
4. The *Science, Technology and Innovation Council* replaced the Advisory Council on Science and Technology, the Council of Science and Technology Advisors and the Canadian Biotechnology Advisory Committee, centralizing S&T advice in a more tightly controlled agency. This development also included the removal of the National Science Advisory as a direct advisor to the Prime Minister; and
5. The creation of a new industrial internship program and increased support for S&T related scholarship programs.

In general, the 2007 report became the cornerstone document for subsequent R&D investments and policy discussions at the federal level. Again, the federal government did not possess any explicit mechanisms or levers to directly control the implementation of these priorities within the educational policies of the provinces and territories. However, a strong argument can be made that despite the acknowledgement of provincial jurisdiction over educational policies and priorities, the report has significantly impacted provincial policies and produced a major shift in the driving narratives of STEM-related research funding at provincial/territorial levels through the attachment of robust new funding opportunities to federal research priorities and programs.

2008 State of the Nation Report: Canada's Science, Technology and Innovation System

This 2008 report produced by the Science, Technology and Innovation Council, a body formed as a result of the 2007 *Mobilizing Science and Technology* report, was initiated in order to 'take stock of Canada's performance in areas that affect our ability to innovate' (STIC, 2009, viii). Ultimately, the document was intended to provide a baseline for future comparisons within innovation-related sectors, specifically as a means to set benchmarks for future achievement, to monitor progress in key areas and to compare Canada's performance to other key comparator jurisdictions.

The general operational premise of the 2008 Report is twofold; in the early 21st century, effective Science & Technology systems have become key components in every nation's economic development and due to a variety of factors, Canada has historically been characterized by weak productivity growth in the S&T sector. In order to redress Canada's S&T deficit, the report laid out a series of recommendations to 'improve Canada's long-term competitiveness and quality of life by fostering three inter-related S&T-based advantages': an Entrepreneurial Advantage, a Knowledge Advantage, and a People Advantage. The report focused on supporting private sector investment, public institutions of education and research, and individual researchers as key mechanisms of fostering innovative capacities within the country. The report is also heavily laden in the context of the economic crisis that began in 2008. Investments in science, technology and innovation are highlighted as key determinants in the country's ability to 'bounce back quickly from the global economic downturn'. In this regard, STEM-related fields are viewed as a cornerstone of overcoming short-term economic stagnation.

The general conclusion of the report is that Canada is a 'solid, middle-of-the-road performer', whereby the country's strengths have 'greatly improved our productivity, our standard of living, and our quality of life' (ibid, 51). Throughout the document, an explicit link is made between Canada's ability to harness its STI productivity and the general quality of life and well-being of its citizenry.

The areas focused on as key metrics to represent Canada's STEM-related productivity and strength are:

1. Business Innovation: Drawing on research by the Council of Canadian Academies, Statistics Canada and the Centre for the Study of Living Standards, this area focuses on the 'critical link between Canadian productivity, economic growth and innovation, specifically through the innovation embedded in technically advanced capital equipment, the development of new resources of value, and improvements in the organization of work' (ibid, 18). The general conclusion of this section is that 'firms that invest more in R&D and innovation have greater value and higher productivity' (ibid, 26). Some of the key indicators highlighted by the report, and which Canada lags behind international comparator jurisdictions, are:

    - Business expenditure on research and development (BERD): As highlighted throughout this report, Canada's BERD performance is average amongst international comparators, and the record indicates that it has been declining since 2002. As a result, this is a key indicator flagged for improvement, as evidenced by the tenor of the 2007 Mobilizing Science and Technology report, and S&T programs analyzed in section 1.6 of this report.

- Percentage of total research and development performed by business; Government support of business research and development; Business investment in machinery and equipment; Venture capital investment; Firm Collaboration;

2. Knowledge Development and Transfer: This section focuses on the ability of Canada's research community, most of which resides within the public higher education sector, to develop new knowledge and mobilize that knowledge amongst relevant stakeholders within the public and private sectors. There is a strong focus on the role of national and global networks as key facilitators of innovation. Some of the key indicators highlighted by the report, most of which place Canada as a world leader, are:

   - Higher Education Performance of R&D; share of business-financed R&D performed by the HE sector; Intramural government R&D

3. Talent: This section focuses on the role of individuals as creators and users of new knowledge. As a result of the premium paid by individuals, key indicators focus on the ability of Canada's educational institutions to develop, retain and attract highly skilled knowledge workers in support of the country's economic development. Key indicators in this section are:

   - Canada's performance on PISA tests; share of the population with tertiary education; science and engineering degrees as a percentage of new degrees; number of business degrees; number of doctoral degrees; total R&D personnel as a percentage of the total workforce; international student enrolment.

1.1.2 Non-government reports

Council of Canadian Academies

The Council of Canadian Academies (CCA) is an independent, not-for-profit corporation, funded by the Government of Canada but operating at arms-length. It supports independent, science-based, expert assessments intended to inform public policy development (CCA, 2012, iii). The CCA work 'encompasses a broad definition of 'science', incorporating the natural, social and health sciences as well as engineering and the humanities' (ibid, iii). The CCA is made up of three national academies: the Royal Society of Canada (the Academies of Arts, Humanities and Sciences in Canada), the Canadian Academy of Engineers, and the Canadian Academic of Health Sciences.

2006 Expert Panel Report on the State of Science and Technology in Canada

In 2006, the Government of Canada, via the Ministry of Industry, requested the creation of a special expert panel to provide advice on the country's strength and capacity in science, technology and innovation. The aim of the panel was to provide a comprehensive overview of the following (CCA, 2006,1):

- The scientific disciplines in which Canada excels in a global context
- The technology applications where Canada excels in a global context
- The S&T infrastructure that currently provides Canada with unique advantages
- The scientific disciplines and technological applications that have the potential to emerge as areas of prominent strength for Canada and generate significant economic or social benefits.

In support of these goals, STI was conceptualized as 'essential for a modern country's ongoing capacity to innovate and compete in the knowledge-based global economy' (ibid, 1). With regard to the above objectives, the expert panel presented the following findings:

- Canada's strengths were in: natural resources; information and communication technologies; health and related life sciences and technologies; and environmental science and technologies.
- However, despite the noted strengths in the above fields, many of the traditional foundation disciplines (e.g., chemistry, microbiology) were judged as losing ground in comparison to the rising performance of other countries.
- Canada's patenting activity is relatively weak in many fields, even those where Canada produced excellent science.
- Canada is judged as doing poorly in knowledge transfers from researchers in universities to innovators in industry. Canada's strength in basic science is not being translated effectively to commercial opportunities and spin-offs. This is a long-standing deficiency in Canada's innovation system that is noted as requiring attention.

2012 *Expert Panel on the State of Science and Technology in Canada*

Similar to the 2006 report, in 2012 the Government of Canada, again through the Ministry of Industry, requested that the Council of Canadian Academies undertake an updated assessment of science and technology in Canada. The purpose of the second expert panel was to answer three primary questions (CCA, 2012a, xi):

1. What is the current state of science and technology in Canada?

   Based on a combination of Publication Counts, Average Relative Citations (measure of the frequency of citations) scores, Specialization Index (measure of Canada's concentration of research activity in particular fields relative to other countries) and Growth Index (change in paper output between 1999-2004 and 2005-2010), Canada's research output and impact has maintained its high research standing over the last decade, despite a clear encroachment by a number of countries with rapidly growing scientific establishments, particularly in Asia and South-east Asia (ibid, 39).

2. What are the scientific disciplines and technological applications in which Canada excels?

Visual and Performing Arts, Clinical Medicine, Physics and Astronomy, Engineering, and Enabling and Strategic Technologies (ibid, 57).

3. In which scientific disciplines and technological applications has Canada shown the greatest improvement/decline in the last five years?

   Visual and Performing Arts, Physics and Astronomy, Biology, Information and Communication Technologies, Engineering, and Communication and Textual Studies (ibid, 53).

2012 Expert Panel Report Science Performance and Research Funding

A third CCA report related to Canada's science and technology research standing was produced in 2012 and focused on the country's federal research funding system. The overarching scope of this report was based on the assertion that 'discovery research in the natural sciences and engineering is a key driver in the creation of many public goods' and that 'scientific advances help catalyze innovation, create new knowledge, foster economic prosperity, improve public health, enable better protection of the environment, strengthen national security and defence, and contribute in a myriad other ways to national and sub-national policy objectives' (CCA, 2012b, xi). This is a holistic vision of the impact that STI has on Canadian society and recognizes a multi-faceted interconnection between the development of STI and all sectors of federal and provincial public policy. The main findings produced by the expert panel, found below, support the above statements (ibid, 96):

- Many quantitative indicators and assessment approaches are sufficiently robust to provide meaningful information about research at the level of nationally aggregated research fields. However, in almost all contexts, multiple indicators should be used to capture information on different aspects of research performance in order to assess science performance at the level of nationally aggregated fields.

- Quantitative indicators should be used to inform rather than replace expert judgment. With respect to national research assessment in the context of funding allocation, the weight of the evidence suggests that the best approach relies on a balanced combination of quantitative data and expert judgment.

- International 'best practices' offer limited insight with respect to science indicator use and assessment strategies. Whether an indicator is reliable or informative often depends as much on the evaluation context as on the construction of the indicator.

- Mapping research-funding allocation directly to quantitative indicators is far too simplistic and is not a realistic strategy. Indicators may reveal useful information, but funding allocation decisions are complex. As a result, any indicator or assessment process, no matter how robust, does not obviate the need for careful, strategic planning and judgment on the part of research funding agencies.

The CCA also presented a more focused analysis of particular features of the Canadian S&T system and policy framework. The main findings indicated that public support for discovery research in Canada occurs within the context of federal S&T strategy and that the Natural Sciences and Engineering Research Council's Discovery Grants Program is the main federal mechanism for supporting discovery research in Canada. An international review of comparable national programs and the research literature found the Canadian program to be highly effective in meeting its goals. However, concerns were raised that the allocation of funding across fields is overly dependent on historical funding patterns.

2012 Let's Talk Science Spotlight on Science Learning: A benchmark of Canadian talent

Let's Talk Science is a national, charitable organization that delivers science learning programs and services to children and youth across Canada. In 2012, the organization joined with AMGEN, a Canadian biomedical firm, to convene a national panel of experts, from both the public and private sectors, in order to produce a study on science learning among Canadian youth (Amgen Canada, 2012). The study established 11 key indicators of science learning to facilitate the identification of benchmarks that the expert panel contended should be monitored and invoked to spur discussion and action on issues relating to science education.

The study was grounded in the following claims (ibid, 8): 'STEM knowledge is directly relevant for many jobs that, according to forecasts, will be in high demand in the coming decades'; that 'beyond the specific body of knowledge, STEM learning is one of the most effective ways to help anyone become more analytical and curious, problem solve, experiment and explore – the very qualities that are needed in the modern workforce'; and that 'a greater degree of science literacy is vital for everyday life, and is a basis for being more engaged and informed citizens, and making better decisions about the world around us'.

N.B. Additional private sector reports that evaluate the Canadian supply of human capital in STEM-related fields, including research, development and innovation, are provided in section 1.3 of this report.

1.1.3 Non-government stakeholder attitudes and opinions

In general, there are very few documents or surveys examining the priority given to STEM fields in the general population or amongst the general education or employer communities in Canada. As a result, the following section provides information on the limited number of surveys and studies found in the popular and academic literature. While they do provide some insight, their representativeness is acknowledged as not comprehensive.

Parents

In 2010, Let's Talk Science, a national organization dealing with science education and literacy, commissioned a national survey of Canadian adults who have children between the ages of 7 and 18 regarding their opinions on the importance of post-secondary science education, scientific study and the role of science in their everyday lives (LTS, 2010a, 1-2). The survey produced the following findings regarding Canadian parents' perspectives on science literacy:

- 84% indicated that science education is highly important for Canadian youth. This was particularly true for parents with a university degree or higher (91%).
- 84% indicated that strong science knowledge is a key for success in any career, and ~60% indicated that jobs and careers over the next 15 years will require more science training and education than they do today.
- However, despite the strong belief in science for career purposes, fewer than 50%

of parents claimed that a basic understanding of science is needed for daily activities, measured along a number of indicators.

- While parents claimed to recognize the growing importance of science education only 23% of parents indicated that they take the time to discuss their children's education goals.
- Despite the above disengagement between parents and children regarding dialogue about education, 55% of parents reported using science-focused TV shows and 52% reported taking children to local science centers or zoos as a means of interesting their children in science.
- In addition, 43% of parents indicated that they help their children with science homework at least once a week.

Students

In 2010, Let's Talk Science also commissioned a national survey of students aged 16-18 regarding their experiences with and perceptions of science, including their intentions for future study. 502 students were surveyed in total. Some key findings are (LTS, 2010b, 1-2):

- 72% indicated that science has relevance in their everyday life.
- 70% responded that science is more important today than when their parents were in school.
- While 81% of students indicated that someone in a science-related profession is best described as intelligent, only 8% stated that they can be described as exciting.
- 70% of students indicate that teachers are highly influential on their perception of science, and 80% indicated that having easy access to a mentor can help them succeed in science.
- Only 24% of students participated in an extra-curricular science program.
- An overwhelming 92% responded that studying science can lead to a well-paid career, and 82% believed that science offers many career options.
- 37% described themselves as not interested at all in pursuing science at a post-secondary level.

One general conclusion that can be drawn from these findings is that there is a disconnect between the positive perceptions about the importance of science to society and the willingness or desire of young people to pursue-science-related careers and interests beyond the bare minimum required by formal school curricula.

Academic community

In 2012, the Council of Canadian Academies undertook two surveys that both investigated the status and reputation of science and technology-related research in Canada; one survey engaged top-cited international researchers (53,954 surveyed with 5,154 respondents) and the other surveyed Canadian science and technology experts (8,513 surveyed and 678 respondents) (CCA, 2012a, xii). Some of the key findings from the international survey are presented below, and in Figure 1.2, and indicate a generally positive view of Canada's S&T research culture and outputs (ibid, 63):

- Among top-cited international researchers asked to evaluate countries on the research produced in their fields with regard to originality, impact and rigor, 37% of respondents ranked Canada as a top S&T country by reputation, fourth highest out of 40 countries. Canada trailed only the United States (94%), United Kingdom (71%), and Germany (63%), and it was on par with France (36%);

- Two thirds of respondents indicated that Canada had significant strength in their field of research compared with other countries;
- Out of the fields ranked highest by international researchers, none are core STEM fields[1];
- Although Canadian S&T experts surveyed rated Canadian S&T as stronger than they did in the 2006 survey (CCA, 2006), they were also more likely to report that it is losing ground in comparison to other countries.

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[1] Canada's highest ranked fields were: Agriculture, Fisheries, and Forestry; Psychology and Cognitive Sciences; Public Health and Health Services; Social Sciences; Economics and Business; and Philosophy and Theology.

Figure 2

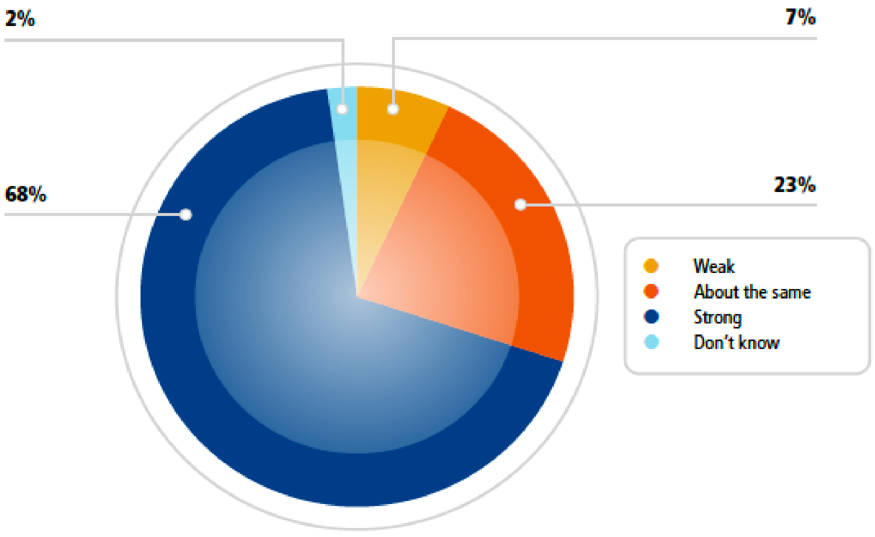

Figure 5.2

Canada's International Reputation in S&T

This figure shows the percentage of respondents identifying Canada as "strong" (5 to 7 on a 7-poin scale), "about the same" (4 on a 7-point scale) or "weak" (1 to 3 on a 7-point scale) in their researc field compared with other advanced countries.

Source: Canadian Council of Academies, 2012b, 67

Some of the key findings from the Canadian survey indicate that while Canadian researchers generally hold the country's S&T systems in high regard, there is some pessimism about the future (ibid, 73):

- The view of Canada's strength, as compared with other advanced countries, is consistent with the findings of the international survey. 57% of respondents indicated that the overall S&T system is strong in comparison to other countries.
- No STEM fields were noted as being on the ascent, whereas over 20% of respondents were concerned that Canada is falling behind in Chemistry, Earth and Environmental Sciences and Enabling and Strategic Technologies.

1.2 Current patterns of STEM provision in schooling, including STEM in primary education, and its influence on later participation in STEM; enrolments in STEM disciplines in secondary education; STEM provision, and participation, in tertiary education; and trends since 2005 in the secondary and tertiary enrolments.

1.2.1 STEM in primary education

There is no national data on enrolment in STEM disciplines in primary education.

1.2.2 STEM in secondary education

There is no comprehensive national data on enrolment in STEM disciplines in Canadian secondary schools. In general, each province and territory requires compulsory enrolment in science and mathematics courses up until grade 10, and normally, but not always, requires one additional credit in science or mathematics after grade 10 in order to graduate. As each province has jurisdiction over its own educational policies, and there is no national repository of data regarding secondary school enrolments, the picture becomes somewhat opaque beyond that. However, there are two sources of complementary data that can help describe the current context of science education in Canadian secondary schools.

First, the 2012 OECD *Education at a Glance* contained a component on the ‘percentage of 15-year old boys and girls planning a science-related career’, which does provide some insight into the engagement of secondary school students with STEM (OECD, 2012b, 82). The results for Canadian students, compared to Australia and the OECD average, are outlined in Table 2 and indicate that Canadian secondary students have a strong interest in science-related careers in relation to international comparators, placing it 6th amongst OECD countries (ibid, 82).

Table 2 - Percentage of 15-year old boys and girls planning a science-related career

	All 15-year olds	**Boys**	**Girls**	**Difference (B-G)**
Canada	42.4	39.8	44.9	5.1
Australia	33.5	34.2	32.8	-1.4
OECD Average	33.2	33.1	33.2	0.1

Source: OECD, Education at a Glance 2012, 82

The second source of information is the 2012 Amgen Canada and Let’s Talk Science (LTS) national study of science education and learning (Amgen Canada, 2012). As part of the study, LTS collected data on optional enrolments in high school science courses in five provinces[2]. Table 3 presents the LTS findings, which indicate the following general patterns; relatively high optional enrolments in English courses in the range of 75-80%; consistent enrolment in Mathematics in the 50% range, with only Ontario falling significantly below at 42%; and wide variability within and across all three science fields, ranging from 32-59% in Biology, 23-40% in Chemistry, and 14-30% in Physics.

Table 3 – Course enrolment as a percentage of total Grade 12 enrolment

Subject									
	Alberta		**B.C.**	**Newfoundland & Labrador**		**Ontario**		**Saskatchewan**	
	2009-10	**2010-11**	**2009-10**	**2009-10**	**2010-11**	**2006-07**	**2007-08**	**2008-09**	**2009-10**
English	N/A		77	75	76	75	75	80	79
Math	51	50	42	51	50	N/A	42	49	48
Biology	43	44	38	57	54	32	32	60	59
Chemistry	34	38	25	29	34	23	23	38	40
Physics	20	21	16	16	18	14	14	30	30

Source: Amgen Canada, 2012, 18

1.2.3 STEM-related performance on international testing

The major international test that provides insight into the general level of proficiency in STEM-related skills and knowledge amongst Canadian secondary school students is the Programme for International Student Assessment (PISA) exam. The PISA study, first initiated in 2000 and most recently conducted in 2009, is a collaborative effort among OECD countries to ‘provide policy-oriented international indicators of the skills and knowledge of 15-year old students and sheds light on a range of factors that contribute to successful students, schools and education systems’ (Knighton et al., 2010, 9). The assessment focuses on three broad areas of knowledge – reading, science and mathematics – in order to provide information of the skills and knowledge possessed by Canadian students that will enable them to become efficient and full participants in society during adulthood (ibid, 9).

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[2] Tracking performed is not comprehensive, and only includes courses that are comparable across provinces.

In 2010, Statistics Canada, Human Resources and Skills Development Canada, and the Council of Ministers of Education, Canada produced a report examining the Canadian results of the 2009 PISA exam, titled *Measuring up: Canadian results of the OECD PISA study* (ibid, 2010). The document presented and summarized the Canadian results in the domains of science and mathematics, and situated them within the international context. Key findings from the report are as follows (ibid, 2010, 29-38):

- Canada performs well internationally in both math and science, scoring well above the OECD average and ranking 8th in math and 7th in science among the 65 participating countries.
- Canadian students' performance in both math and science remained stable over time.
- The lack of improvement in Canada, coupled with increased performance in other countries, has resulted in an overall decline in Canada's global standing in both fields.
- Accounting for gender, males outperformed females in both science and math, a finding that is consistent across time in Canada. While this dynamic is also present in math on average across OECD countries, in contrast females performed equally as well as males in science on average across OECD countries.
- Results varied significantly by Canadian province, which is beyond the purview of this report, but is an additional factor for consideration.

1.2.4 National science curricula

Given the absence of a federal ministry of education in Canada, no policy levers exist in the country for a centralized approach to curricular formation or reform at either the primary or secondary school level. However, in the absence of binding policy levers there exist a number of stakeholder groups who regularly make non-binding policy recommendations. The most prominent of such groups is the Council of Ministers of Education, Canada (CMEC). CMEC is an inter-governmental body founded in 1967 by the ministers of education from each Canadian province and territory. It acts as a cross-provincial forum for policy discussions and the organization undertakes activities, projects and initiatives in areas of mutual interest as a means to consult and cooperate with the federal government, as well as international governments and organizations.

For this report, CMEC's 1997 *Common Framework for Science Learning Outcomes: Pan-Canadian Protocol for Collaborations on School Curriculum* (The Framework) (CMEC, 1997) will be analysed with regard to its impact on national STEM discourse at primary and secondary schooling levels. It represents the only major document put forward at the national level regarding science curricula in the primary and secondary systems over the last 20 years.

In general, the Framework built on a number of pre-existing documents and initiatives in the Canadian educational landscape, specifically: the 1984 Science Council of Canada *Report 36: Science for Every Student: Education Canadians for Tomorrow's World*; the 1993 CMEC Victoria Declaration, a document which provided general direction for national curriculum compatibility; and the 1997 CMEC Pan-Canadian Science Project, an initiative focused on producing a framework for general and specific scientific learning outcomes from kindergarten to Grade 12.

The Framework focused on the development of scientific literacy amongst Canadian students at all levels, highlighting the goal in its mandate statements and learning outcomes. The thematic focus of the document was on facilitating an understanding of the *foundations of science education* amongst young Canadians. The foundations of science were described as ‘the development of an understanding of science and technology and the relationship to society and the environment; skills of inquiry; knowledge of science concepts; and attitudes to support the acquisition and application of scientific and technological knowledge’ (Milford et al., 2010, 373). These conceptualizations and priorities were developed into five specific goals for Canadian science education (CMEC, 1997):

- Encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours.
- Enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others.
- Prepare students to critically address science-related societal, economic, ethical, and environmental issues.
- Provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations, and engages them in science-related hobbies appropriate to their interests and abilities.
- Develop in students of varying aptitudes and interests in knowledge of the wide variety of careers related to science, technology, and the environment.

Milford et al. (2010) investigated the impact that the Framework has played in curricular development within the 9 participating provinces[3] since its inception. This was undertaken through document analysis, interviews with selected informants and a survey of key stakeholders. Their findings indicate that all but two provinces specifically refer to the Framework as ‘a design element in their science curricula … the Framework’s foundation statements, content strands and learning outcomes were apparent to different degrees across the curricula’ (ibid, 2010, 375). However, references to technology and S&T-related careers were limited, as were references to the incorporation of indigenous knowledge in science curricula (ibid, 375).

Despite the presence of Framework themes and statements within many, if not all, of the provincial curricula, Milford et al. contend that the idea of scientific literacy is at times so vague and general that it is difficult to determine many of the particular details associated with the implementation of the Framework at provincial levels. In addition, they argue that ‘the nature of technology as a design process, which differs from the nature of science as an inquiry process, focused on adapting the environment to alleviate problems facing people and meeting their needs, was not made explicit in the Framework and curricula as it was in other international reform documents and curricula’ (ibid, 379).

While the Framework can be used as an entry-point into understanding Canadian science curricula, it suffers from the issue of an ‘expiry date’; the document is extremely out-dated and does not reflect the vast STI developments that have occurred over the past 15 years, particularly the development of ICTs and the ubiquity of personal technological devices. As such, the Framework is something of an antiquity already, despite its engagement with the role of S&T education and societal development, and despite the fact that it remains the most recent national policy document on science curriculum at both the primary and secondary education levels.

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[3] Quebec was not a participant and Nunavut had not yet been formally established as a separate territory with its own educational jurisdiction in Canada

1.2.5 Provincial science curriculum – Ontario

While there have not been any major developments in science curriculum at the federal level in over 15 years, each province has undertaken its own reform processes aimed at bringing the education system in line with scientific and technological developments. The following section presents the Ontario curriculum reforms of 2007 (Grades 1-8) and 2008 (Grades 9-12) as an example of provincial processes. Ontario has been chosen for two primary reasons: a) the provincial government's focus on education as a cornerstone of its mandate, and b) the researchers' familiarity with the political economy of this jurisdiction. Under the Liberal Government, a centre-left party in the Canadian context, primary and secondary education were heavily targeted for reform throughout the mid 2000s and Premier Dalton McGuinty came to be known, rightly or wrongly, as the 'Education Premier'.

Grades 1-8 (~Ages 6-13)

Reform of the Ontario curriculum in general, and the science curriculum in particular, was spurred by the recognition that 'science and technology underpin much of what we take for granted', including 'the places in which we live and work and the ways in which we communicate with others'. The impact of science and technology on our lives will continue to grow. Consequently, scientific and technological literacy for all has become the overarching objective of science and technology education throughout the world' (Government of Ontario, 2007, 3). To this purpose, the Liberal government of Ontario established the following three goals for science and technology in the primary and secondary education sectors as the cornerstones of its reform process (ibid, 3; Government of Ontario, 2008a, 2008b):

- To relate science and technology to society and the environment.
- To develop the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving.
- To understand the basic concepts of science and technology.

In pursuit of these goals, the new curriculum laid out a series of expectations, both general, in terms of 'the knowledge and skills that students are expected to demonstrate by the end of each grade', and specific, in terms of the 'expected knowledge and skills in greater detail'. The following expectations were put forward with regards to the above goals (ibid, 11):

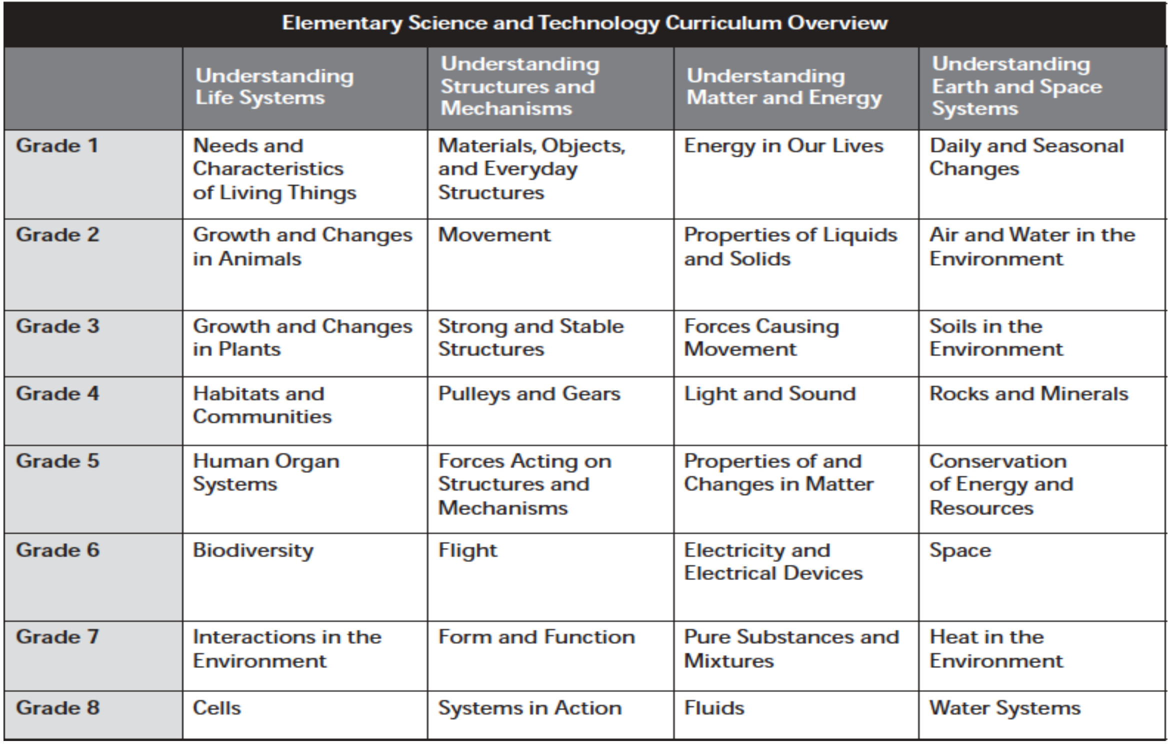
- The overall expectation of relating science and technology to society and the environment (STSE) and the related cluster of specific expectations are placed first to better align the curriculum with the teaching and learning of science and technology, and to emphasize the importance of scientific, technological, and environmental literacy for all students. In addition, the STSE expectations set the context for developing the related skills and conceptual knowledge that are necessary for making connections between scientific, technological, social, and environmental issues. Many of the STSE expectations also focus on various aspects of environmental education.
- The skills needed for developing scientific and technological literacy are outlined in the second overall expectation and in the related specific expectations found under the heading Developing Investigation and Communication Skills.
- The conceptual knowledge requirements are outlined in the third overall expectation and in the related specific expectations found under the heading Understanding

Basic Concepts.

Modified expectations are presented for students requiring instructional, environmental and assessment accommodations, including students with English as a second-language and the implementation of anti-discrimination education in the S&T program for students from under-represented populations (ibid, 38-39).

The intention of the new curriculum is for students throughout the primary and secondary education systems to gain an understanding of ‘fundamental concepts in science’ in order to ‘provide a framework for the deeper understanding of all scientific knowledge – a structure that facilitates integrated thinking as students draw from the knowledge base of science and see patterns and connections within the sub-disciplines of science, and between science and other disciplines’ (Government of Ontario, 2008a, 3). Table 4 presents an overview of the thematic cornerstones for the grades 1-8 science and technology curriculum.

Table 4: Ontario science curriculum, grades 1-8



Elementary Science and Technology Curriculum Overview

	Understanding Life Systems	Understanding Structures and Mechanisms	Understanding Matter and Energy	Understanding Earth and Space Systems
Grade 1	Needs and Characteristics of Living Things	Materials, Objects, and Everyday Structures	Energy in Our Lives	Daily and Seasonal Changes
Grade 2	Growth and Changes in Animals	Movement	Properties of Liquids and Solids	Air and Water in the Environment
Grade 3	Growth and Changes in Plants	Strong and Stable Structures	Forces Causing Movement	Soils in the Environment
Grade 4	Habitats and Communities	Pulleys and Gears	Light and Sound	Rocks and Minerals
Grade 5	Human Organ Systems	Forces Acting on Structures and Mechanisms	Properties of and Changes in Matter	Conservation of Energy and Resources
Grade 6	Biodiversity	Flight	Electricity and Electrical Devices	Space
Grade 7	Interactions in the Environment	Form and Function	Pure Substances and Mixtures	Heat in the Environment
Grade 8	Cells	Systems in Action	Fluids	Water Systems

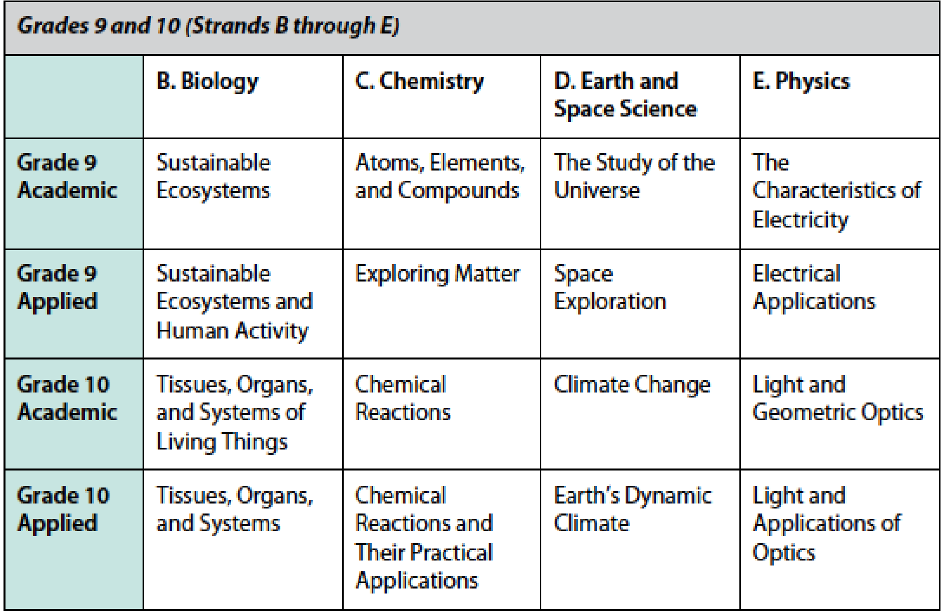
Source: Government of Ontario, 2007, 19

Grades 9-10 (~Ages 14-15)

The focus of Ontario's secondary school science curriculum reform was to develop 'scientific literacy' and 'a sense of wonder about the world around them' within every student (Government of Ontario, 2008a, 2). By revising the curriculum, the Government of Ontario intended for every student to acquire the skills necessary to thrive in 'a science-based world', and 'reflects new developments on the international science scene and is intended to position science education in Ontario at the forefront of science education around the world' (ibid, 2). In pursuit of this, the three major goals of the curriculum remained consistent with those put forward for the grades 1-8 cohorts.

The curricular reform process organized the grade 9 and 10 science courses into five strands of knowledge. The first focuses on essential skills of scientific investigation and career exploration, while the remaining four strands cover specific scientific content areas; life systems (biology), matter and energy (chemistry), earth and space systems (earth and space science), and structures and mechanisms (physics). The new curricula required all Ontario students to take one science course in both grade 9 and 10. Courses in grade 9 and 10 are offered in either *academic* or *applied* streams, with the former focusing primarily on theory and abstract concepts, incorporating applications as appropriate, and the latter focusing on essential concepts of a subject in order to development a students' knowledge and skills through practical applications and concrete examples (ibid, 10). Students who complete the grade 9 courses in their stream may proceed to either the academic or applied course in grade 10, which prepare students for particular destination-related courses in grade 11 and 12. Table 6 provides an overview of the two streams available to grade 9 and 10 students in each of the four science strands.

Table 5 – Grade 9 and 10 science-based academic and applied course streams



Grades 9 and 10 (Strands B through E)				
	B. Biology	**C. Chemistry**	**D. Earth and Space Science**	**E. Physics**
Grade 9 Academic	Sustainable Ecosystems	Atoms, Elements, and Compounds	The Study of the Universe	The Characteristics of Electricity
Grade 9 Applied	Sustainable Ecosystems and Human Activity	Exploring Matter	Space Exploration	Electrical Applications
Grade 10 Academic	Tissues, Organs, and Systems of Living Things	Chemical Reactions	Climate Change	Light and Geometric Optics
Grade 10 Applied	Tissues, Organs, and Systems	Chemical Reactions and Their Practical Applications	Earth's Dynamic Climate	Light and Applications of Optics

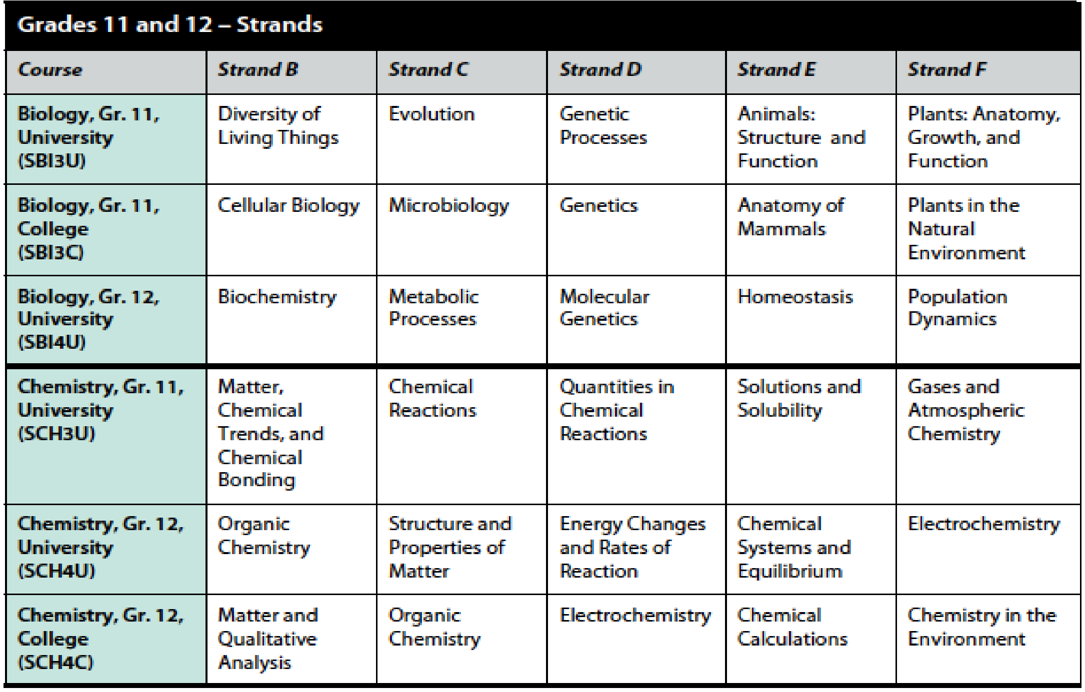
Source: Government of Ontario, 2008a, 11
N.B. Strand A, absent from the above chart, is a general scientific investigation skills program that is similar for all course streams.

Grades 11-12 (~Ages 16-18)

The final two years of Ontario's secondary school science curriculum (grades 11 and 12) focus on fostering students' abilities to 'recognize, interpret and produce representations of scientific information in forms ranging from written and oral reports, drawings and diagrams, and graphs and tables of values to equations, physical models and computer simulations. As students' scientific knowledge and skills develop through the grades they will become conversant with increasingly sophisticated forms and representations of scientific information' (Government of Ontario, 2008b, 10). Senior science curricula are focused on integrating technologies in the learning and doing of science in order to help students develop investigation skills.

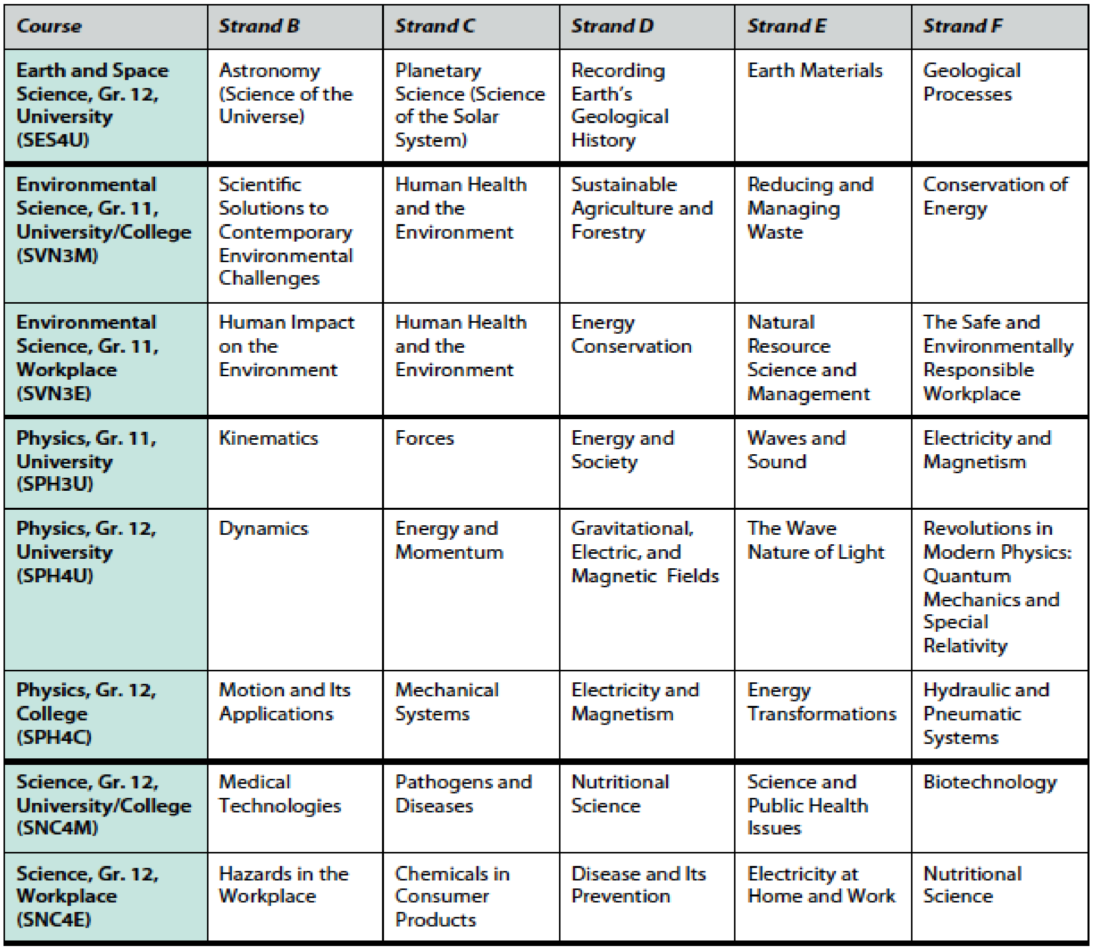
Courses in grades 11 and 12 are offered in four streams; university preparation, college preparation, university/college preparation, and workplace preparation. Table 6 presents an overview of the course options available for the two senior years at Ontario secondary schools.

Table 6 – Ontario science-related course strands for grade 11 and 12



Grades 11 and 12 – Strands

Course	*Strand B*	*Strand C*	*Strand D*	*Strand E*	*Strand F*
Biology, Gr. 11, University (SBI3U)	Diversity of Living Things	Evolution	Genetic Processes	Animals: Structure and Function	Plants: Anatomy, Growth, and Function
Biology, Gr. 11, College (SBI3C)	Cellular Biology	Microbiology	Genetics	Anatomy of Mammals	Plants in the Natural Environment
Biology, Gr. 12, University (SBI4U)	Biochemistry	Metabolic Processes	Molecular Genetics	Homeostasis	Population Dynamics
Chemistry, Gr. 11, University (SCH3U)	Matter, Chemical Trends, and Chemical Bonding	Chemical Reactions	Quantities in Chemical Reactions	Solutions and Solubility	Gases and Atmospheric Chemistry
Chemistry, Gr. 12, University (SCH4U)	Organic Chemistry	Structure and Properties of Matter	Energy Changes and Rates of Reaction	Chemical Systems and Equilibrium	Electrochemistry
Chemistry, Gr. 12, College (SCH4C)	Matter and Qualitative Analysis	Organic Chemistry	Electrochemistry	Chemical Calculations	Chemistry in the Environment



Course	Strand B	Strand C	Strand D	Strand E	Strand F
Earth and Space Science, Gr. 12, University (SES4U)	Astronomy (Science of the Universe)	Planetary Science (Science of the Solar System)	Recording Earth's Geological History	Earth Materials	Geological Processes
Environmental Science, Gr. 11, University/College (SVN3M)	Scientific Solutions to Contemporary Environmental Challenges	Human Health and the Environment	Sustainable Agriculture and Forestry	Reducing and Managing Waste	Conservation of Energy
Environmental Science, Gr. 11, Workplace (SVN3E)	Human Impact on the Environment	Human Health and the Environment	Energy Conservation	Natural Resource Science and Management	The Safe and Environmentally Responsible Workplace
Physics, Gr. 11, University (SPH3U)	Kinematics	Forces	Energy and Society	Waves and Sound	Electricity and Magnetism
Physics, Gr. 12, University (SPH4U)	Dynamics	Energy and Momentum	Gravitational, Electric, and Magnetic Fields	The Wave Nature of Light	Revolutions in Modern Physics: Quantum Mechanics and Special Relativity
Physics, Gr. 12, College (SPH4C)	Motion and Its Applications	Mechanical Systems	Electricity and Magnetism	Energy Transformations	Hydraulic and Pneumatic Systems
Science, Gr. 12, University/College (SNC4M)	Medical Technologies	Pathogens and Diseases	Nutritional Science	Science and Public Health Issues	Biotechnology
Science, Gr. 12, Workplace (SNC4E)	Hazards in the Workplace	Chemicals in Consumer Products	Disease and Its Prevention	Electricity at Home and Work	Nutritional Science

Source: Government of Ontario, 2008b, 18-19
N.B. Strand A, absent from the above chart, is a general scientific investigation skills program that is similar for all course streams.

1.2.6 Expanding participation in STEM learning amongst under-represented groups

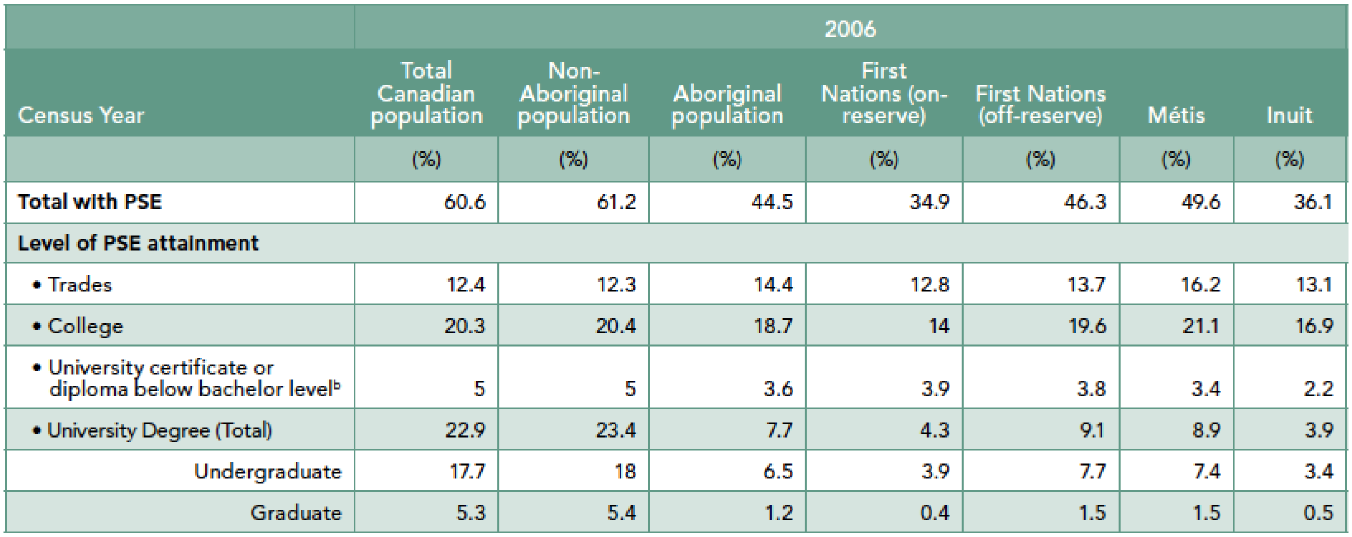
Aboriginal population

One of the major under-represented groups within Canada's PSE system, which has increasingly become a focus of government initiatives and non-governmental researchers in recent history, is the country's aboriginal population. Access to and attainment of post-secondary education is recognized as a key component in social and economic success for Aboriginal youth, and the success of Aboriginal people in PSE has significant implications and spill-overs for Canada's social and economic prosperity (Mendelson, 2006; CCL, 2007, 2009). In this regard, the Canadian context is not unique, as many countries founded on a colonial legacy continue to grapple with how best to meet the needs of the historically under-served group within national milieus.

Science education has become a key point of discussion in this regard, as the knowledge-based economy proliferates throughout the international educational discourse and advanced training, skills and credentials in the sciences are increasingly in demand within the labour market. However, within the Canadian literature examining Aboriginal participation in STEM-related fields of study there is a recognition that 'the values and philosophy of Western science (particularly as these are typically exemplified in the classroom) and the values and philosophies held by many Aboriginal people and communities, makes the issue of increasing Aboriginal participation in science and technology a particularly thorny one' (CCL, 2007, 2). While this report is not the proper medium for a more comprehensive analysis of these philosophical tensions and pedagogical incongruities, these issues are noted as major inhibitors of aboriginal participation and success in STEM-related fields throughout Canada's formal education systems, particularly at the tertiary level.

At the national level, the most recent data available on Aboriginal post-secondary attainment comes from the 2006 Census, whereby it was estimated that 44.5% of the country's Aboriginal population had completed a post-secondary credential (certificate, diploma or degree), significantly below the non-Aboriginal rate of 61%. However, Aboriginals were noted as having attained college and trade diplomas and certificates at roughly equivalent rates as non-Aboriginal Canadians (Statistics Canada, 2008). Table 7 presents comparative Aboriginal vs. non-Aboriginal attainment levels for all post-secondary sectors.

Table 7: Aboriginal and non-Aboriginal populations aged 25-64, by level of PSE attainment, 2006



	2006						
Census Year	Total Canadian population	Non-Aboriginal population	Aboriginal population	First Nations (on-reserve)	First Nations (off-reserve)	Métis	Inuit
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Total with PSE	60.6	61.2	44.5	34.9	46.3	49.6	36.1
Level of PSE attainment							
• Trades	12.4	12.3	14.4	12.8	13.7	16.2	13.1
• College	20.3	20.4	18.7	14	19.6	21.1	16.9
• University certificate or diploma below bachelor level[b]	5	5	3.6	3.9	3.8	3.4	2.2
• University Degree (Total)	22.9	23.4	7.7	4.3	9.1	8.9	3.9
Undergraduate	17.7	18	6.5	3.9	7.7	7.4	3.4
Graduate	5.3	5.4	1.2	0.4	1.5	1.5	0.5

Source: Statistics Canada, *Aboriginal identity (8), highest certificate, diploma or degree (14), major field of study – classification of instructional programs, 2000 (14), area of residence (6), age groups (10a), and sex (3) for the population 15 years and over of Canada, provinces and territories, 2006 Census – 20% sample data 2006 Census of population (Ottawa, March 4, 2008),* Catalogue no. 97-560-XWE20066028.

In terms of the data available for analysing Aboriginal participation in STEM-related courses and programs, Canada lags behind its American counterparts in the tracking of Aboriginal student learning, particularly the absence of standardized tests through which to measure standing and progress in science courses. However, field of study was accounted for within the 2006 Canada Census, which provides some level of analysis for Aboriginal participation in the STEMs at the tertiary level. Table 8 presents data on areas of education for the entire population, including those who report not having attained a postsecondary certificate, diploma or degree. It is clear that education in STEM-related fields is low for the Aboriginal population, though not significantly lower than the general population. However, given the policy developments that have occurred over the past 6 years, these numbers do not present the most current picture.

Table 8: Comparison of Areas of Education: Aboriginal vs. Non-Aboriginal, tertiary education, 2006

Area of Education	% Aboriginal	% Non-Aboriginal
No postsecondary certificate, diploma or degree	62	49
Education	2	3
Visual and performing arts, and communication technologies	1	2
Humanities	2	3
Social and Behavioural sciences and law	4	6
Business, management and public administration	7	11
Physical and life sciences and technologies	1	2
Mathematics, computer and information sciences	1	3
Architecture, engineering, and related technologies	9	11
Agriculture, national resources and conservation	1	1
Health, parks, recreation and fitness	6	7
Personal, protective and transportation services	4	3

Source: Statistics Canada, 2006 Census

Gender gap

A second target group that, while not under-represented in the general PSE population, has been historically under-represented in STEM-related fields of study is women. With regard to the presence of this historical dynamic within federal policies and discourse, it is extremely interesting to note that gender was not raised once throughout the entirety of the 2007 *Mobilizing Science and Technology* federal policy paper (Industry Canada, 2007), nor was it raised in the 2012 Council of Canadian Academies report on the state of S&T in Canada (CCA, 2012a).

In recent history, women have comprised a stable majority of the undergraduate population in Canadian universities; in 1998/1999 and 2008/2009 academic years, women made up 55% and 56% of the undergraduate body at the national level, respectively[4]. By field of study, the most recent Statistics Canada data does provide insights into the gender divide in terms of degrees, diplomas and certificates granted by field of study at Canadian universities and colleges. Table 9 presents university credential data from the 1998/1999 and 2008/2009 academic years by field of study and gender, including female-male ratios.

While female graduates increased as a percentage of male graduates in almost all fields, the only STEM-related field where this held true was in the physical and life sciences (134%-113%), whereas despite a relative increase in total female participation over the 10 year period, female graduates in the two mathematics and engineering-related categories declined (48%-43% and 29%-28%, respectively). This data indicates that the barriers to female participation in STEM-related fields remain problematic and historical asymmetries have not been overcome, despite increased female participation on the whole at the undergraduate level.

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[4] Source: Statistics Canada, Postsecondary Student Information System, CANSIM Table 477-0013

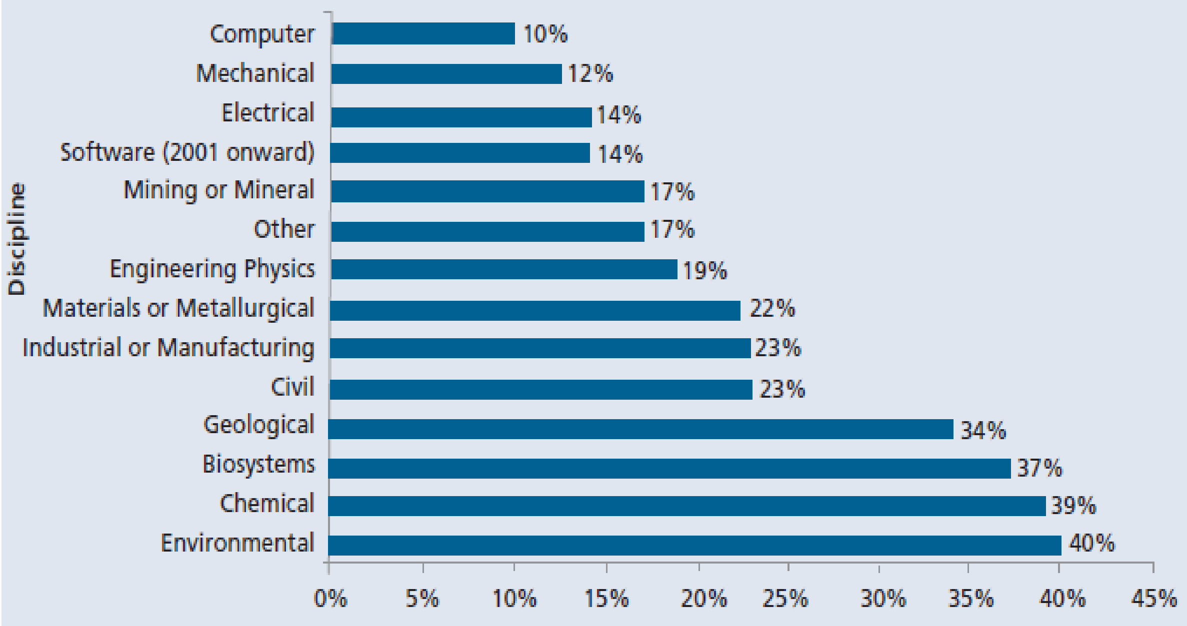
Table 9 - Number of degrees, diplomas and certificates granted by universities, by sex of graduate and field of study, 1998 and 2008

Field of Study	**1998/1999**			**2008/2009**		
	Men	**Women**	**% (W-M)**	**Men**	**Women**	**% (W-M)**
Total for all programs	71,949	100,125	139	97,620	146,721	150
Education	5,576	15,963	286	3,315	21,090	636
Social and behavioural sciences, and law	13,725	24,171	176	16,563	33,600	202
Health, parks, recreation and fitness	5,010	11,487	229	6,168	20,673	335
Business, management and public administration	14,199	16,293	114	23,448	26,499	113
Agriculture, natural resources and conservation	1,716	1,539	89	1,788	2,271	127
Visual and performing arts, and communications technologies	1,734	3,519	202	3,135	6,213	198
Humanities	7,401	12,963	175	9,342	16,854	180
Physical and life sciences and technologies	7,272	8,280	113	7,944	10,680	134
Mathematics, computer and information sciences	4,713	2,253	48	5,715	2,496	43
Architecture, engineering and related technologies	10,116	2,910	29	15,660	4,479	28

Source: Statistics Canada, Postsecondary Student Information System, CANSIM Table 477-0014

Figure 3 provides longitudinal analysis of female enrolment in engineering sub-disciplines at Canadian postsecondary institutions.

Figure 3 - Average share of female enrolment in undergraduate engineering disciplines, 1991 to 2007



Source: Prism, 2009, 21

Table 10 presents equivalent data for the 2006/2007 academic year, the most recent year of data that is publicly available. This data indicates that the gender gap in the math and engineering-related fields are even more significant than at the university level, with female-to-male ratios of 30% and 16%, respectively.

Table 10 - Number of certificates, diplomas, and degrees granted by college, by sex and field of study, 2006/2007

Field of Study	**Men**	**Women**	**% (W-M)**
Total for all programs	64,044	93,726	146

Education	516	3,384	655
Social and behavioural sciences, and law	2,382	11,151	468
Health, parks, recreation and fitness	4,074	21,111	518
Business, management and public administration	12,003	23,667	197
Agriculture, natural resources and conservation	1,773	1,260	71
Visual and performing arts, and communications technologies	3,363	6,003	178
Humanities	10,748	17,667	164
Physical and life sciences and technologies	528	630	119
Mathematics, computer and information sciences	4,452	1,374	30
Architecture, engineering and related technologies	18,051	2,952	16

Source: Statistics Canada, Postsecondary Student Information System, CANSIM Table 477-0016

At the graduate level, specifically at the doctoral level, female participation has historically been much lower than amongst men. As evidenced by the above data, this is the inverse of the Canadian undergraduate scenario. However, as seen in table 11 below, this gap has narrowed significantly over the past 20 years, to the point where gender parity is becoming a more attainable outcome.

Table 11 - Proportions of men and women with earned doctorates, 1993 to 2008

Year	**Men (%)**	**Women (%)**	**Year**	**Men (%)**	**Women (%)**
1993	67	32	2001	57	43
1994	69	31	2002	57	43
1995	69	31	2003	58	42
1996	66	34	2004	56	44
1997	64	36	2005	56	44
1998	64	36	2006	57	43
1999	61	39	2007	55	45
2000	59	41	2008	56	44

Source: Statistics Canada, Postsecondary Student Information System, CANSIM Table series 477-0013, University enrolments, by registration status, program level, Classification of Instructional Programs, Primary Grouping (CIP_GP) and sex, annual (number)

When examining the gender gap by field of study, the available data indicates that the gap has historically been magnified within STEM-related fields, with women representing a significantly smaller percentage of doctoral graduates. The most recent national data (2008) examining the proportion of men and women among doctoral graduates by field of study, presented below in Table 12, highlights the disparity across STEM-related fields. Though the gap is less prominent in the physical and life sciences than in mathematics and engineering-related fields, it is clear that the increased parity within the total doctoral pool has not translated into increased participation with many STEM-related fields in the Canadian PSE system.

Table 12 - Proportion of men and women among doctoral graduates, by selected fields of study, 2008

Field of Study	**Men (%)**	**Women (%)**
Total for all programs	56	44
Education	32	67
Social and behavioural sciences, and law	40	60
Health, parks, recreation and fitness	41	59
Business, management and public administration	49	51
Agriculture, natural resources and conservation	52	48
Visual and performing arts, and communications technologies	52	45
Humanities	55	45
Physical and life sciences and technologies	58	42
Mathematics, computer and information sciences	75	26
Architecture, engineering and related technologies	78	23

Source: Statistics Canada, Postsecondary Student Information System, CANSIM Table series 477-0013, University enrolments, by registration status, program level, Classification of Instructional Programs, Primary Grouping (CIP_GP) and sex, annual (number)

Recognizing the persistence of gender asymmetries in Engineering-related fields, Engineers Canada, the national organization that regulates the practice of Engineering in Canada and licenses the country's professional engineers, collaborated with the Canadian Council of Technicians and Technologists, the national organization that carries out the same function for 14 applied science and engineering technology disciplines, conducted a study on the state of female participation in Engineering fields (Prism, 2009). The study included a literature review and interviews/focus groups with female students enrolled in STEM-related courses at the high school level in 5 regionally discrete cities: Calgary, Halifax, Montreal, Toronto and Winnipeg. Four key findings were put forward to explain the weak female participation in the pertinent fields (ibid, 1-2):

- A large majority of women do not have a good understanding of what engineering and technology careers entail and therefore cannot aspire to those careers. Only 12.5% had heard of National Engineering Month, while only 9% had heard of National Technology Week.
- Among the minority of young women who had a better understanding of engineering and technology careers, often through a parent or relative, this greater knowledge did not translate into an interest in postsecondary studies in engineering or technology.
- A large majority of young women expressed negative perceptions about engineering and technology occupations, with many equating them to construction or outdoor work, working in a cubicle and relating primarily to computers and machines, rather than people.
- Compared to young men, young women have fewer role models encouraging them to consider engineering and technology careers, including high school teachers and industry professionals.

Supplementing all of the above data, a 2007 Ministry of Industry report, based on the 2001 Statistics Canada Census, presents evidence on the role of gender in advanced degree programs (PhD) in Science and Engineering disciplines in Canadian universities, including their uptake within the labour market. Some of the key findings (McKenzie, 2007, 3-4):

- Of the ~57,000 doctorates earned in science and engineering in Canada, the gender split is close to 80/20 in favour of men.
- Of a total of just over 100,000 employed doctorate holders in 2001, nearly 73% were men.

- In contrast to both of the above figures, in 2001, women accounted for 47% of employed Canadians and 57% of university graduates.
- Literature and current data indicate a clear correlation between earnings, age and gender. For example, earnings are higher with age and female workers earn less.

1.3 Student uptake of STEM programs, and factors affecting student performance and motivation.

The following section presents a general overview of enrolment and graduation numbers by field of study in Canada at both undergraduate and graduate levels of study, specifically between 2005 and 2010. This section will provide basic data on the graduation rates amongst Canadian tertiary education students across fields of study, which will help contextualize the presentation and analysis of Canadian STEM-related policies in sections 1.4 and 1.5 of this report.

While Statistics Canada compiles and disseminates data on graduation rates, the data provided in the following section is drawn from OECD sources in order to maintain a comparable categorization across the various sections of this report. Statistics Canada is the source of the Canadian data obtained by the OECD.

1.3.1 Number of university graduates (ISCED Type 5A), by field of study, 2005-2010

Table 13 provides an outline of trends amongst first-cycle undergraduate graduations rates within Canada's university sector. Major categories are presented in **bold** and sub-fields are presented in *italics*. The major finding from this data is that graduation rates in some science-related fields have increased significantly over the past five years, particularly in comparison to non-science-related fields. Life and physical sciences have witnessed particularly staggering increases, outpacing all other disciplines and sub-disciplines by a wide margin.

However, STEM-related fields of study have not risen across the board, with a near-collapse of the computing field, and very limited increases in mathematics and engineering. The Engineering and Health fields experienced moderate increases across time; they were either at or slightly below national averages and thus do not represent significant items for further analysis. While it would be interesting to analyze the graduation rates within various STEM-related sub-fields of the Health category in order to determine where exactly increases were occurring within this broad category, such data were not provided in a meaningful way by the OECD database.

Table 13 – Canadian undergraduate graduates, by field of study, 2005-2010

Field of study (OECD.stat category #)	**2005**	**2010**	**% Change**
Education (140)	27,144	24,717	-9%
Humanities (200)	29,625	27,917	-6%
Social sciences, business and law (300)	78,147	83,385	7%
Sciences (400)	23,214	28,909	25%
Life Sciences (420)	9,219	14,470	57%
Physical Sciences (440)	3,078	6,480	111%
Mathematics and Statistics (460)	2,769	3,157	14%
Computing (480)	8,148	4,802	-41%
Engineering, Manufacturing and construction (500)	17,343	18,838	9%
Engineering and engineering trades (520)	13,761	13,840	1%
Agriculture (600)	2,079	1,774	-15%
Health and welfare (700)	21,039	23,691	13%
Health (720)	16,119	18,805	16%
Social services (740)	4,920	4,886	-1%
Services (800)	5,007	7,513	50%
Total (9000)	201,069	225,614	12%

Source: OECD.stat database

1.3.2 Number of graduates from advanced research programming, by field of study, 2005-2010

Table 14 presents the results of advanced research programming when isolated from the general Type 5A data set. In general, increases in graduate education far outpace undergraduate enrolment increases. The findings also indicate a much more pronounced differentiation process by field of study since 2005, with all STEM-related fields and sub-fields experiencing significant increases. The policy levers that precipitated this change will be outlined in sections 1.5.

It is interesting to note that while undergraduate graduations in the Health sub-field increased at a moderate rate (13%) during the period under analysis, the number of advanced research graduates in the field experienced a massive decrease during the same time frame (-47%). There does not appear to be a particular policy lever for this type of change highlighted in the literature, and this would be a fruitful area of further analysis if highlighted as pertinent.

Table 14 –Graduation rates, advanced research programming (PhD), by field of study, 2005-2010

Field of study (OECD.stat category #)	**2005**	**2010**	**% Change**
Education (140)	408	319	-22%
Humanities (200)	501	546	9%
Social sciences, business and law (300)	777	1034	33%
Sciences (400)	990	1928	95%
Life Sciences (420)	417	977	134 %
Physical Sciences (440)	408	602	48%
Mathematics and Statistics (460)	120	167	39%
Computing (480)	117	182	58%
Engineering, Manufacturing and construction (500)	627	1036	65%
Engineering and engineering trades (520)	498	831	65%
Agriculture (600)	153	135	-12%
Health and welfare (700)	573	292	-49%
Health (720)	549	263	-47%
Social services (740)	24	29	20%
Services (800)	69	87	26%
Total (9000)	4116	5416	31%

Source: OECD.stat database

1.3.3 Distribution of enrolment by field of study, 2009

The OECD database does not provide graduate numbers by field of study for the Canadian community college system. However, enrolment numbers are provided using the ISCED 5B and 5A categorization scheme (OECD, 2011a, 85). This data allows for a comparison between Canada, Australia and the average amongst OECD countries. While the data provided in Table 15 does not allow for a longitudinal comparison, it does provide a general overview of the current rate of enrolment in Canada's community colleges, particularly in comparison with enrolment in university degree programs.

With regard to this reports' focus on STEM-related student uptake, it is clear from the data presented below that the community college sector is less engaged in the provision of Science-specific programming. While data on sub-fields is not available for this indicator, the higher number of enrolments in both the Health and Welfare and Engineering, Manufacturing and Construction categories are most likely due to the high-level of vocational and technical programming present in these categories at the community college lever. In general, Type-B institutions are mandated with a focus on vocationally oriented certificates and diplomas, and it is not within their mandate to provide basic arts and science programming.

Table 15 – Enrolment by field of study, 2009

	Type-A Programmes			**Type-B Programmes**		
	Canada	Australia	OECD	Canada	Australia	OECD
Humanities, Arts and Education	21.4	21.3	23	12.3	11.6	19.9
Health and Welfare	11.6	17	12.4	18.6	19.3	18
Social sciences, Business and Law	30.7	37.9	34.6	33.7	41.3	25.4
Services	3.1	3.3	3.3	7.4	4.4	11.6
Engineering, Manufacturing and Construction	9.1	9.3	13.2	14.1	15.2	14.5
Science	10.2	9.9	10.1	5.2	5.3	6.4
Agriculture	0.9	1	1.8	1.8	2.3	1.6
Other/Unspecified	12.9	0.2	1.6	7.1	0.5	2.6

Source: OECD, 2011a, 85

1.3.4 Number of doctoral graduating students by country, 2005 & 2009

The Council of Canadian Academies 2012 Expert Panel concluded, ‘Canada has the largest number of post-secondary graduates in the OECD – a strong basis to build from – but it is not translating this into high numbers of doctoral graduates who will conduct S&T in the future’ (CCA, 2012a, 135). This does not necessarily play out in terms of the overall numbers provided by the OECD data. While Canada’s overall numbers remain significantly below comparator countries like the US, Germany and the UK, in general, between 2005 and 2009, the number of doctoral graduates from Canadian universities grew at a percentage rate higher than all comparable OECD countries (Table 16). However, while this growth is encouraging, the low raw number of graduating doctoral students remains a concern moving forward.

Table 16 – Doctoral graduation rates, select countries, 2005-2009

Country	**2005**	**2009**	**Growth Rate (%)**
United States	52,631	67,716	28.7
Germany	25,952	25,527	-1.6
United Kingdom	15,778	17,651	11.9
Japan	15,286	16,476	7.8
France	9,578	11,941	24.7
Republic of Korea	8,449	9,912	17.3
Australia	4,886	5,808	18.9
Canada	4,116	5,440	32.2

Source: OECD, 2011a, Education at a Glance

1.3.5 Science and engineering graduates at doctorate levels, 2009

In general, Canada ranks poorly in comparison to OECD averages for both its graduation rate of all adults with master’s and doctoral degrees; 9% against an OECD average 12.7% for the former and 1.2% compared to a 1.5% OECD average for the latter (OECD, 2012b, 25). Although Canada tends to have a low share of PhDs by international standards, 54% of its doctorate degrees awarded in 2008 were in science and engineering, ranking it fourth of 38 countries participating in the 2011 OECD

Science, Technology and Industry Scoreboard 2011.

1.4 Access of STEM graduates to the labour markets, and labour market take-up of STEM knowledge and skills

With the growth of the knowledge-based economy over the past two decades, and the correlating responses from government and industry, there has been an increased scrutiny in Canada on the ability for postsecondary programs to meet the needs of the labour market (Riddell and Sweetman, 1999; Finnie & Usher, 2007; Walters & Frank, 2010). This has manifested in a variety of ways, from increasing the marketable skills of graduates to supporting more research and developing opportunities between universities and industry. However, the overarching narrative present in both public and private sectors has been that the attainment of higher levels of education, and the subsequent development of specialized skills, will produce a higher return on investment for both individuals and society (Finnie & Usher, 2007; Conference Board of Canada, 2007; Martin Prosperity Institute, 2007). While there are extensive debates, both in Canada and internationally, regarding the nature of the relationship between PSE credentials, skill development and labour market outcomes, this report will focus on the labour market outcomes and uptake of PSE graduates in STEM-related fields, as opposed to the underlying reasons for such outcomes.

1.4.1 Labour market take-up and future demand of STEM-related graduates

In 2008, a branch of the Government of Canada, Human Resources and Skills Development Canada (HRSDC), produced a *10-year Outlook for the Canadian Labour Market (2008-2017)* report (HRSDC, 2008), which summarized historical trends in labour supply, labour demand, demographic shifts and population growth as a means of forecasting future supply and demand within the noted ten year period. One aspect of this study is a focus on where the economy is anticipated to grow and the types and domains of jobs forecasted as required in order to meet this demand.

At a general level, university graduates' share of the labour force is anticipated to rise from 22.9% in 2007 to 25.7% by 2017 and college graduates' share will increase from 34.6% to 35.7% in the corresponding years (ibid, 19). Therefore, it is anticipated that in 2017, 61.4% of the labour force will possess a postsecondary degree or diploma, compared to 57.5% in 2007 and below 40% in 1990 (ibid, 20). This dynamic is anticipated to significantly reduce the share of the labour force with a high school diploma or less over the same period, placing an increased premium on the attainment of tertiary credentials.

The structure of the Canadian economy that is anticipated to correspond with the above supply-side shifts includes a drastic increase in the demand for high-skill occupations, specifically those requiring university, college or management training (ibid, 35). In terms of specific sectors, the Natural and Applied Sciences (NAS) are forecasted as growing at rates slightly above the overall growth rates. This sector includes engineers, computer and information systems professionals, physical science professionals, and life science professionals (ibid, 73).

Between 2008 and 2017, employment growth in the above occupations is expected to be slightly above average in the Canadian economy, marked by an annual growth rate of 1.5%, compared with a 0.9% rate for all occupations combined (ibid, 74). In 2007, the NAS sector accounted for 7.8% of non-student employment in Canada, just over 1.2 million workers, and this group is expected to represent 14% of all new jobs over the 10-year period (ibid, 74). It is anticipated that this growth will be driven by increases in professional business services, especially those related to engineering, computer science, and research and development, specifically in the civil, mechanical, electrical and chemical engineering fields, and other technical inspectors and regulatory officers (ibid, 74).

In 2009, R&D activities provided employment for 149,923 full-time equivalent positions, the most recent year for which such data is available. Professionals such as scientists, engineers and senior R&D administrators made up 58% of this total. Skilled technicians and technologists comprised a further 32%, and the remaining 10% comprised administrative and maintenance support (OECD, 2011b, 7).

1.4.2 Science-related graduates among 25-34 year-olds in employment, 2009

A key metric of note to the conversation of STEM-related uptake amongst Canadian students is the proportion of science-related graduates in employment in the tertiary leaving cohort over the past 10 years (25-34 year-olds). Table 17 indicates that Canada is slightly above the OECD average for this indicator, but graduates from Type-B programming represent a larger share of the total science-related graduates in employment in Canada, particularly in comparison to the Australian and OECD averages. This is quite interesting in light of the data presented in Table 15, above, which clearly indicates that the level of enrolment in science-related programs is much lower in the Type-B sector.

Based on the data at hand and in the context of the differentiated institutional mandates of universities and colleges in the various Canadian provincial systems, the most likely cause of this scenario is the theoretical focus of Canadian university programming, as opposed to the applied or vocational focus of their counterpart community colleges. There appears to be a significant disconnect between career preparations in science-related fields between the two sectors. The vocational focus of Type-B institutions may result in the graduation of students who are better equipped to attain employment within science-related fields. Another factor may be that given the limited age bracket of the OECD survey (25-34), many graduates from Type-A institutions may go on to study in graduate or advanced research programmes that cause them to enter the labour market for the first time after the age of 34. Given the significant difference between Canada and both Australia and the OECD average, it would interesting to investigate whether or not there are significant differences in the institutional mandates of Type-B institutions in comparator jurisdictions that would explain the difference in Type-B employment rates.

Table 17 - Science-related graduates among 25-34 year-olds in employment, 2009

	Total	**Type-A Programmes**	**Type-B Programmes**	**Ratio of A-B**
Canada	2,146	1,340	807	1.66
Australia	2,362	1,924	438	4.39
OECD	1,829	1,242	416	2.98

Source: OECD, 2011a, p. 87

1.4.3 Unemployment rate by field of study, Canada

An additional set of indicators that can provide insight into the uptake of STEM graduates in the Canadian context is the unemployment rates for PSE graduates who completed their studies in STEM-fields. One caveat is that the major Canadian survey used to examine the success of postsecondary students within the labour market, Statistics Canada's National Graduate Survey (NGS), has not been conducted since 2005, therefore the impact of policy developments since that time are not able to be presented or analyzed at this time. Another caveat is that the data is only presented under the following headings, a) Ontario (Table 18) and b) Canada without Ontario (Table 19).

Table 18 – Unemployment rate, by field of Study, Ontario

	Class of 2005 (%)	**Class of 2000 (%)**
All fields of study	7	7
Life Sciences	4	5
Engineering	9	X
Computer, math and physical sciences	6	6
Psychology and social sciences	5	7
Humanities	15	17
Education and other fields of study	4	X

Source: Statistics Canada, National Graduate Survey (Class of 2005, 2000)

Table 19 – Unemployment rate, by field of study, Canada without Ontario

	Class of 2005 (%)	**Class of 2000 (%)**
All fields of study	7	7
Life Sciences	6	5
Engineering	9	10
Computer, math and physical sciences	6	7
Psychology and social sciences	6	6
Humanities	16	13
Education and other fields of study	3	4

Source: Statistics Canada, National Graduate Survey (Class of 2005, 2000)

1.4.4 Industry perceptions of STEM-related human capital

2010 Conference Board of Canada Report Innovation Catalysts and Accelerators: The Impact of Ontario's Colleges' Applied Research

The Conference Board of Canada (CBC) is a not-for-profit applied research organization that conducts research and analysis on economic trends, particularly in relation to public policy issues. The membership of the organization is predominantly major Canadian private sector and industry firms, but it also draws on experts from the Canadian academic community and government agencies through the Board of Directors. The 2010 report, which focused primarily on the Ontario Colleges of Applied Arts and Technology (CAATs), discussed the value of human capital and the need for post-secondary institutions to provide education and training that more directly meets the needs of employers, specifically with the aim of increasing the productivity of the Canadian economy through more investment in innovation-related education. In this light, the CBC argued that Canada's college-level institutions are well positioned to bridge the public and private sectors by responding to unmet labour market demands (CBC, 2010, 6).

According to the report, applied research capacities and activities are a leading contributor to economic development and innovation, as well as the training of highly-skilled personnel that can stimulate innovation among Canadian firms, contribute to local economic development and enhance the quality of education and training in Canadian post-secondary institutions (ibid, 7). The CBC's annual report card of Canadian economic performance has consistently graded the country's innovative capacity as a key weakness for future economic growth, and marked the development of high-quality personnel with the skills necessary to stimulate innovation as a key component for future education policy in the country. In a survey conducted by the CBC of public and private-sector leaders, two of the key barriers to innovation highlighted were a 'lack of in-house expertise' and 'weak innovation skills' necessary to conduct research and pursue innovation (ibid, 14).

Focusing on the Ontario experience, the CBC focused on the need for students and faculty to have better connections and to be more informed about the needs, challenges and opportunities of industry as the key mechanism to develop the requisite skills demanded by the marketplace. The report highlights Ontario's colleges as key incubators of innovation-related skills and attitudes because their institution mandates are aligned with meeting local economic development needs. Applied research at the CAATs improves students' technical and employability skills, but more importantly leads to improvements in students' entrepreneurial and innovation skills (ibid, 20).

2012 Canadian Council of Chief Executives *Competing in the 21st Century Skills Race*

The Canadian Council of Chief Executives (CCCE) is a not-for-profit organization composed of the CEOs of major Canadian firms. The organization conducts research, consultation and advocacy on a range of business-related public policy issues, with a specific mandate regarding Canada's competitiveness agenda. In 2012, the organization conducted a research report examining Canada's achievements in three broad areas: 'general literacy and numeracy; the number of students enrolled in STEM programs; and the development of skills considered to be particularly important for innovation, such as critical thinking, collaboration and adaptability' (Orpwood et al., 2012, 3). The intent of the report was to provide an overview of Canadian talent development in order to evaluate Canada's place within the global knowledge economy.

The over-arching conclusion of the report is that literacy and numeracy demands have evolved to a point that possessing basic skills in these areas is no longer sufficient to ensure the country's capacity to compete in the most important sectors of the economy. While knowledge and proficiency in STEM-related fields are highlighted as important, the report claims that 'there are skill sets and cultural attitude that are not based on specific subject areas but which are closely related to the capacity for innovation…described as generic skills, advanced skills, enabling skills and 21st century skills' (ibid, 8). In addition, 'all imply a blending of specialized knowledge with abilities to reason in appropriate ways, to be critical, creative and innovative, to collaborate, to be adaptive, flexible and capable of risk-taking' (ibid, 8). The challenge posed by 21st century skills is that they are 'difficult to teach, at least in a direct sense, and even harder to assess. We therefore have little evidence of their achievement until after the period of formal education' (ibid, 8).

The report references the Conference Board of Canada's annual economic indicator report, which gives Canada a C grade in terms of participation in STEM education, and a D grade in terms of the post-graduate attainment, specifically the overall number of PhD graduates per 100,000 people. The conclusion is made that Canada needs more graduates with advanced qualifications and more graduates in STEM fields to enhance innovation and productivity growth, and to ensure a high and sustainable quality of life for all Canadians (ibid, 9).

In conclusion, while the CCCE concludes that Canada's education system is strong and vibrant, there is concern over the future ability to meet new demands put forward by the global knowledge economy, specifically due to low participation in STEM and advanced research programs. The report also laments the lack of a national forum for addressing a range of skills-related issues, owing primarily to the distribution of power over educational issues to the provinces and territories (ibid, 18).

1.5 Strategies, policies and programs used to enhance STEM at all levels of education, and a judgment concerning the success of those programs

Due to provincial jurisdiction over education, national science-related policies and programs have had to be developed at arms-length from explicit educational policies, most often under broader notions of economic development. Federal jurisdiction has thus been felt most forcefully through the funding of research, the establishment of immigration policies (directly and indirectly related to the attraction of high-skill workers and post-secondary students), and infrastructure development. This section will focus on R&D support and immigration policies in order to further understanding of the current state of STEM education, and related policies and programs, in Canada.

1.5.1 Key Science, Technology, and Innovation Programs

Tri-Council Granting Agencies

Most of the federal government support for research and scholarship at Canadian academic institutions is distributed through competitive processes operated by three specialized Councils with jurisdiction over their respective areas of focus; the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council (NSERC), and the Social Sciences and Humanities Research Council (SSHRC). These Councils jointly share the responsibility for administering, adjudicating, and monitoring the distribution of federal research grants in pursuit of high-quality research and in service to the social and economic well-being of Canada and its citizens. Given the nature and focus of STEM education and STEM-related disciplines, this review focuses on the NSERC program as the leading federal research-granting program with relation to STEM education.

The Social Sciences and Humanities Research Council, with a subject matter focus on the social sciences and humanities, has the objective of supporting research that will primarily add to our ‘understanding and knowledge of individuals, groups, and societies – what we think, how we live and how we interact with each other and the world around us’ (retrieved from science.gc.ca website).

The Canadian Institutes of Health Research has a subject matter focus on improving or having an impact on health and/or the production of more effective health services and products and/or the strengthening of the Canadian health care system, including: bio-medical research; clinical research; research respecting human health systems and services, and; research into the health of populations, societal and cultural dimensions of health and environmental influences on health.

While the research funded by SSHRC and CIHR are at times cross-disciplinary, stretching into select STEM disciplines, it is the Natural Sciences and Engineering Research Council that is the agency most directly related with STEM-education, research and development. The following section provides a more in-depth overview of the NSERC program, mandate and initiatives.

NSERC

The Natural Sciences and Engineering Research Council (NSERC) was established in 1978 and remains the primary federal government program focused on making Canada a ‘country of discoverers and innovators for the benefit of all’. In this pursuit, NSERC supports students, post-doctoral fellows, university professors and university-industry research partnerships with a subject matter focus on the Natural Sciences and Engineering (NSE), other than the health sciences. NSERC is funded directly by the Canadian Parliament and reports to it through the Ministry of Industry. NSERC's programs are intended to map directly onto the 2007 federal science and technology strategy paper, *Mobilizing Science and Technology to Canada's Advantage* (Industry Canada, 2007), specifically in support of Canada's people, knowledge and entrepreneurial advantages.

The awarding of NSERC funding occurs through national peer-reviewed competitions, predominantly on an annual basis, with awards generally committing to between 12 and 36 months of funding. In the 2012-13 fiscal year, NSERC will invest over $1 billion in postsecondary research and training in the NSE, $816.7 million (~80%) of which is in direct support of the five priority areas outlined in the 2007 and 2009 S&T strategy papers; Environment, ICTs, natural resources, health, and manufacturing.

In fiscal year 2012-13, NSERC's budget represents 10% of the federal government's expenditures on science and technology, and 20% of all university R&D funding in the natural sciences and engineering.[5] In order to situate the magnitude of NSERC as part of the broader Tri-Council the following table 20 outlines the total base funding allocated by the Government of Canada between the years 2007 and 2012. It is clear that while all three agencies have seen reduced support, NSERC has experienced the least variance over the past five years. In addition, NSERC has received the highest level of funding, three times as much as the Social Science and Humanities Research Council:

Table 20 - Granting Council Base Funding, 2007-2012 (constant $2010, millions)

	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**% Change (2007-2012)**
SSHRC	383.7	358.1	350.4	342.5	342.6	-10.7%
NSERC	1057.9	1051.8	070.6	1050.7	1044.8	-1.2%
CIHR	1017.8	989.8	1001.8	980.8	976.3	-4.1%
Indirect Costs	327.8	335.7	330.9	322.4	325.9	-0.8
Total	2787.2	2735.4	2753.6	2696.4	2698.6	-3.2%

Source: CAUT, Analysis of Federal Budget 2012, p. 4.

NSERC carries out its mandate through the following three-pronged approach, which operates in support of the priority areas outlined by the Government of Canada's 2007 S&T Report:

- Invest in people; highly skilled science and engineering professionals in Canada. This occurs through the direct funding of undergraduate, graduate and postdoctoral students and their research projects, as well as the Canada Research Chairs program.
- Invest in discovery; high quality Canadian-based competitive research in the natural sciences and engineering. This occurs through support of major research equipment and resources, specifically through major research support grants.
- Invest in innovation; knowledge and skills in the natural sciences and engineering that are transferred to and used productively by the user sector in Canada. This occurs through support for a variety of research centres, chairs and internship programs that target industry-university-government collaboration and partnerships in a number of forms.

Tri-Council postgraduate programs: Banting and Vanier

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[5] http://www.tbs-sct.gc.ca/rpp/2012-2013/inst/nse/nse01-eng.asp#s1

In support of the above goals, NSERC, and the other two Tri-Council agencies, have created a number of cornerstone programs aimed at attracting and retaining top graduate and post-graduate research talent at Canadian universities and, to a much lesser extent, colleges. The two primary programs created to achieve this goal are the Vanier Canada Graduate Scholarships (VCGS) program and the Banting Post-Doctoral Fellowships (Banting) program[6]. One of the major differences between the Vanier scholarship and the other Tri-Council doctoral awards is that recipients can be either Canadian or international but must be enrolled at a Canadian university, whereas the CGS and basic NSERC awards are only available to Canadian citizens and permanent residents, but recipients can be enrolled at either Canadian or international institutions. This is emblematic of the programs' mandate to attract and retain top talent.

The Vanier CGS is the most prestigious doctoral level scholarship funded by the Canadian government. Started in 2007, the program is intended to 'attract and retain world-class doctoral students and to establish Canada as a global centre of excellence in research and higher learning'[7]. It is built upon the basic structure of the Canadian Graduate Scholarships (CGS), created in 2003 with similar goals but the CGS have significantly lower funding packages. While the basic CGS package totals $35,000 at the doctorate level, roughly $15,000 dollars more than the traditional Tri-Council doctoral awards, the Vanier CGS funding package totals $50,000 per year for three years[8]. Roughly 165 Vanier scholarships are awarded on an annual basis, split evenly between the three Tri-Council agencies. Given the recent implementation of the program, no systematic evaluations have been conducted by the Tri-Council or the Government of Canada in order to determine the added value of the program to Canada's research community. However, the Vanier program is a clear step by the Government of Canada to improve the competitiveness of its universities and colleges in attracting top international students and retaining high quality Canadian students.

At the post-doctoral level, the Banting program was established for the same general purposes as the VCGS, targeting both Canadian and international post-doctoral students. The intention of the program is that 'recipients of Banting Postdoctoral Fellowships will, upon completion of their fellowship, be well positioned to contribute to the continued growth of Canada's research capacity and the country's economic and social prosperity' and 'the program reinforces Canada's reputation as a magnet for talent and a global centre of excellence in university research'.[9]

In support of these goals, the Banting program operates with the following conditions for recipients with regard to where recipients may hold their awards: for Canadian citizens and permanent residences, the award may be held at either a Canadian or international institution, however, for international recipients, the awards can only be held at Canadian institutions. In total, the program is limited to 140 total recipients, spread across two cycling cohorts of 70 two-year awards. Awardees receive $70,000 per year, though these funds are taxable. Of the 73 awards granted in 2011-2012, 26 were to international applicants, including 11 of the 26 NSERC awardees.

The general take-away from the range of awards currently supported by the Canadian government across all disciplines is that over the past 10 years a concerted effort has been made by the Government of Canada to augment the domestic research

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[6] http://banting.fellowships-bourses.gc.ca/about-a_propos/back-gene-eng.html

[7] http://www.vanier.gc.ca/eng/scholarship_details-renseignements_generaux.aspx

[8] ibid.

[9] http://banting.fellowships-bourses.gc.ca/about-a_propos/benefits-avantages-eng.html

environment through the support, attraction and retention of top Canadian and international talent at both graduate and post-graduate levels. This spans across all disciplines, however, as evidenced by the total budget allotment to NSERC, STEM-related research and researchers remain the top priority within the Government of Canada's research goals. This will be further expanded upon through the analysis of the government's Networks of Centers of Excellence program, particularly the sub-programs that focus on STEM-related research and supporting greater industry-academia relations.

Mitacs-Globalink Internship Program

Mitacs-Globalink is a new public-private partnership aimed at supporting short-term summer internships for international undergraduate students at Canadian universities in partnership with local research industries. The stated goal of the program is to 'introduce Canada as a world-leading research and innovation destination to top undergraduate students from around the world'[10]. Through the internship process, students will be exposed to local entrepreneurs, researchers and business leaders in order to advance their professional skills and forge lasting networks with Canadian academics and industry. For the 2013 cohort, the targeted sending countries selected by Mitacs-Globalink are India, China, Brazil and Mexico, which represents a strategic investment in some of the world's fastest growing economies and rapidly expanding pools of research and development talent.

The focus on top talent is supported by rigorous application standards, which focus on students in their final years of undergraduate students within the top percentiles of their class. In addition, students are selected with a preference for STEM-related research interests. The program is incentivized through full funding for students' travel, visa and accommodation costs, a weekly stipend of $200 dollars, offsetting local transit fees, and all associated institutional fees at the hosting campus required to access the required facilities[11]. The program has expanded from 17 internships in 2009 to 211 in 2012.

The success of the undergraduate program has spawned a second-generation program that supports previous Mitacs-Globalink recipients if they are accepted for graduate studies at a Canadian university. Mitacs supports $10,000 of the total fellowship per year for up to two years, with the remainder paid for by the host institutions, though details of the fellowship vary by university.

Networks of Centres of Excellence: Industrial Research and Development Internship Program

The NCE system is a tripartite arrangement between universities, industry and government in support of the development of world-class research and researchers, as well as facilitating technology transfer between universities and industry (Salazar & Holbrook, 2007, 1135). Fisher et al. (2001) describe the NCE system as, 'one of the flagship initiatives in a federal policy framework promoting the commercialization of academic science and academy–industry partnerships'. The NCE is referred to as a 'system' because since its inception it has incorporated four sub-programs with distinct, yet mutually reinforcing, objectives: the Networks of Centres of Excellence (NCE) program; the Centres of Excellence for Commercialization and Research (CECR) program; the Business-Led NCEs (BL-NCE) program; and the Industrial Research and Development Internships (IRDI) program.

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[10] http://www.mitacs.ca/globalink/2013-student-program-guide

[11] ibid.

The major student-level skills development component of the NCEs is the Industrial Research and Development Internship (IDRI) program, the only NCE program that directly targets the professional development of students. Through IDRI, recipient organizations are awarded funds to take on graduate students and post-doctoral fellows through a competitive review process in order to provide recipients with the opportunity to apply their scientific and technical expertise to ‘private sector needs and problems’ (NCE, 2011, 1). The aim of the program is to foster short- and long-term cooperation between universities, colleges, S&T graduates and private sector firms. Operating for between four to six months at a minimum value of $10,000 dollars per intern, the program contributes up to 50% of the intern’s salary, with the private firm responsible for the remainder. In total, the program is intended to support 1000 interns per year, with a requirement that 300 interns per year will be new interns to the program (ibid, 3).

The NCE programs exemplify the types of interventions and supports that the Government of Canada has implemented over the past 10 years, particularly since the unveiling of its Science and Technology policy in 2007. While the broader NCE program supports all disciplines of research, the various sub-programs are primarily concerned with fostering research, development and training of STEM disciplines, specifically in support of stronger industry ties and market interests.

Canada Research Chairs (CRCs)

The Canada Research Chairs program is the main federal government initiative targeted at attracting and retaining top Canadian and international researchers. Responding to a perceived deficit in Canada’s innovation system (see Government of Canada, 1996), the program was created in 2000 in order to boost the system and enhance the quality of the country’s researcher pool. The CRC program is the flagship researcher-focused initiative of the federal government and marked a radical change in the government’s relationship with the Canadian research community.

The program is intended to align with the strategic outcomes of Tri-Council funding bodies and is expected to play a prominent role in the Government of Canada’s 2007 Science and Technology Strategy, *Mobilizing Science and Technology to Canada’s Advantage* (Industry Canada, 2007). In addition, the Canadian Foundation for Innovation program, functions in direct support of the CRC program by providing infrastructure funding via the Leaders Opportunity Fund, totaling $279 million as of 2010 with a close to 100% applicant success rate for CRCs (Science Metrix, 2010, 3, 45). In sum, the CRC and associate programs represent the most direct presence that the federal government had ever had in post-secondary research affairs, though it still retained the optics of respecting the provincial jurisdiction over educational policies (Prichard, 2000).

The official mandate of the program was to bring post-secondary institutions and researchers into closer alignment with federal Science and Technology policies and priorities, and to facilitate strategic research planning at Canadian PSE institutions. The specific goals of the program were four-fold: to attract and retain leading researchers, both Canadian and international; to increase the capacity of universities to produce and apply new knowledge; to assist universities in developing comparative advantages in strategic areas of research, and; to contribute to the training of highly qualified personnel (Science Metrix, 2010, i). In support of this mandate, the program allowed institutions to provide internationally competitive funding, infrastructure and support in order to attract and retain researchers.

The original mandate of the program supported the creation of 2,000 research chairs at

Canadian universities and colleges, though as of March 2012 only 1,819 chairs were actively filled[12] (CRC website). The Chairs were separated into two tiers; Tier 1 chairs, focused on established researchers with outstanding research contributions, are associated with a $200,000 annual transfer to the host institution for seven years, whereas Tier 2 chairs focus on exceptional emerging researchers and are associated with a $100,000 annual transfer for five years. As of March 2012, 812 Tier 1 and 1,007 Tier 2 chairs were filled, with 446 Chairs recruited from outside of Canada, 206 of which are expatriates and the remaining 240 are international recruits. Of the 1,819 chairs, 466 are female (25.6%) and 1,347 are male (74%), with the gender not indicated for 6 Chairs. In terms of the programs overall success, the 2010 CRC Evaluation produced some key findings:

- Based on an international and domestic scan of the similar programs, the CRC program is relatively unique; 'Very few research funding programs of its type—government funded and led, providing substantial levels of funding for universities across the country, and inscribed within an overarching, long-term, strategic national scientific and economic objective—could be found elsewhere' (ibid, 18-19).
- Overall, 68% of CRCP chair holders originated from within Canada, and 32% came to, or returned to, Canada from international institutions. About half of the CRCP Chairs were used for retention (ibid, 23).
- The CRC program helps alleviate barriers to attraction and retention by enhancing or complementing the availability of research funding, the capacity to support students and research staff, and the quality of the research environment at the host university, as well as by conferring status and prestige (ibid, 27-30).
- All sources agree that the CFI component of the CRCP is crucial to the attraction and retention of leading researchers in Canadian universities (ibid, 32-33).
- The bibliometric analysis shows that CRCP chairholders produce a greater number of peer-reviewed papers, are cited more frequently, and are more often published in high impact journals than comparable groups of leading researchers. CRCP chairholders also disseminate their research results via many other modes, including conference proceedings and posters, books and book chapters, patents, creative works, etc (ibid, 34-36).
- The CRCP—more than other chair programs—is clearly associated with the creation and enhancement of research centres and clusters in areas of strategic importance. Over 80% of current CRC Chairs conduct research in one of more of the four priority research areas targeted by the 2007 Government of Canada S&T Strategy (ibid, 20).
- The CRCP directly contributes to the capacity of chairholders to have external organizations take up the new knowledge they have generated. The R&D performed by chairholders has also led to the commercialization of technologies; 'as many as 40% of chairholders (and 50% of NSERC chairholders) reported the use of their research in industry. Indeed, some chairholders seek to develop products and production methods that are commercially relevant, often in partnership with industry (including with investments from firms)' (ibid, 39).
- The CRCP supports the attraction of high-quality students and research staff to Canadian universities, such as by contributing to the presence of leading researchers or by enhancing the research and training environment (ibid, 66-67).

Genome Canada (GC)

The most prolific thematically-focused research program funded by the Canadian government since the year 2000 has been Genome Canada (GC), a national program

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[12] http://www.chairs-chaires.gc.ca/about_us-a_notre_sujet/statistics-statistiques-eng.aspx

operating under the umbrella of Industry Canada that funds and coordinates projects in genomics and proteomics research through six distributed Genome Centres established within publicly-funded universities across the country and a variety of stand-alone research projects.

The programs vision and mandate is to ‘position Canada as a world leader in genomics and proteomics research; and to develop and implement a national strategy in genomics and proteomics research for the benefit of all Canadians in key strategic areas (e.g., health, environment, forestry, fisheries, etc.)’ (KPMG, 2009, 3). In addition, GC has committed itself to ‘concentrating its future investments in research programs and initiatives which will bring the greatest economic and social benefit to society’ (GC, 2011, 4).

Between 2000 and 2011, the Government of Canada has directly committed $980 million to GC projects and centres, and GC has raised over $1 billion in co-funding commitments as a supplement to government funding (GC, 2011, 2). This money has gone towards supporting 162 large-scale research projects and international partnerships, S&T Innovation Centres and the six regional Genome Centres. The major mechanism for fund distribution has been to provide up to 50% of the funding for large-scale research projects and 100% for science and technology platforms, which provide access for researchers to sophisticated technology and expensive research infrastructure (KPMG, 2009, 3).

In terms of the impact that GC has had on the Canadian research landscape, the 2009 evaluation concluded ‘there has been a transformative impact of GC on Canadian genomics research. Canada is now a visible and respected world player’ (ibid, 2009, 11). The GC structure has successfully attracted and retained top international researchers, significant socio-economic applications and benefits have been highlighted as direct spin-offs of GC research, particularly in the field of health care, and over a third of evaluation respondents had applied their research or were engaged in active development, for commercial products or applications (ibid, 7-8).

1.5.2 Assessment of these programs and concluding observations

As noted throughout the paper, Canada’s federal arrangements delegate responsibility for education and higher education to the provinces, while the Government of Canada plays a significant role in research and development, and has initiated a number of major funding programs since 2000. Assessing the overall success of provincial policies related to education in STEM fields is challenging, in large part because the provinces have different curricula, goals, and policy arrangements. Generally speaking, Canada’s schools are regarded as performing quite well, including in STEM fields. While there are important variations in performance by province, Canadian students have performed quite well on the Program for International Student Assessment (PISA) exams. Canadian scores on these examinations are well above the OECD average, and Canada ranks in the top ten in both math and science results.

In terms of tertiary education, Canada has high participation rates and high levels of degree attainment compared to other OECD peers. Maintaining or increasing levels of access to tertiary education is a key policy issue in all provinces. While there have been examples of provincial policies that were explicitly designed to expand enrolment in STEM related areas, such as the Access to Opportunities Program in Ontario in the late 1990s, the more common approach has been to generally support the overall expansion of participation rates and leave the decision on the appropriate balance of enrolment by program in the hands of the institutions. The share of students in non-university (type B) programs is higher than in many other OECD nations. While overall participation rates are high, there is an increased concern about addressing the problems associated with those groups that are being left behind. While participation rates of Canada's aboriginal peoples are increasing, they continue to be very low compared to the population as a whole, in large part reflecting low levels of secondary school completion. There continue to be concerns with gender balance in some STEM fields, especially in specific specializations within engineering.

Several provinces have taken steps over the last decade to support the expansion of graduate level education, including the expansion of doctoral programs. Support for expansion has generally been across all fields of study, and so the expansion of graduate students in STEM fields is in part simply a function of a broader wave of support for overall expansion, and in part influenced by the increasing availability of research funding and graduate student financial support under federal government initiatives.

The available evidence suggests that graduates are successfully transitioning into the labour market. Generally speaking, unemployment rates for graduates of STEM fields are low or comparable with other program areas.

While the provincial governments have strongly supported increasing access to tertiary education, the federal government has been making major investments in Canada's innovation strategy, especially in supporting the development of research talent, research infrastructure, and research activity. STEM fields, as well as many areas within health research, have been major beneficiaries of these initiatives, though it is important to note that most of these initiatives support research across the range of research fields (STEM and non-STEM) with a greater emphasis on science and technology.

One of the most high-profile of these initiatives is the Canada Research Chairs Program. While there were some initial concerns with gender balance of appointed chairs, the overall evaluations of the program have been very positive and the CRCP has become the flagship example of federal government investment in research talent. The program was designed to both retain top Canadian talent and attract leading scholars, and linkages between the CRCP and the Canada Foundation for Innovation allowed institutions to provide top researchers with start-up infrastructure support that simply could not be financed by the CRCP alone. The Canada Excellence Research Chairs Program, designed to attract leading international researchers and teams through awards of $10 million over seven years, was announced in 2008 and the first chairs were awarded in 2011. While this new, highly competitive program has been successful in attracting a small number of top researchers in selected areas, it is too early to assess the overall impact of this initiative.

Canada's overall science and technology strategy appears to be working. The government has made major investments in direct support for research, research infrastructure and human resources, and these investments have been very well received by the higher education sector. These initiatives have balanced curiosity-driven research supported by the granting council competitions, with more focused, targeted support in strategic areas. It has balanced support for talent (through the CRC program and expanded scholarship programs) with infrastructure (through CFI).

The continuing concern, repeated by reviews of science and technology policy for the last four decades, is the low level of private-sector (business enterprise) investment in research and development compared with many other developed nations. This was a key theme in the recent OECD Economic Review of Canada (2012c), and while the government has focused considerable attention on mechanisms designed to support or leverage private-sector investments, there continue to be major concerns in this area. However, these concerns with private-sector investments have served to reinforce the importance of continuing to invest in research performed by the public higher education sector, and in talent, through investments in research training and in attracting and retaining top researchers, as key components of Canada’s innovation strategy.

Bibliography

Amgen Canada & Let's Talk Science. (2012). *A spotlight on science learning: A benchmark of Canadian talent.* Retrieved from http://www.letstalkscience.ca/spotlight.html

Canadian Association of University Teachers. (2012). *CAUT Analysis of Federal Budget 2012*. Ottawa: CAUT.

Canadian Council on Learning. (2009). The state of aboriginal learning in Canada: A holistic approach to measuring success. Ottawa: CCL.

---. (2007). *The cultural divide in science education for Aboriginal learners*. Ottawa: CCL.

Conference Board of Canada. (2010). *Innovation catalysts and accelerators: The impact of Ontario Colleges' Applied Research.* Ottawa: CBC.

Council of Canadian Academies. (2012a). *The state of science and technology in Canada, 2012*. Ottawa: CCA.

---. (2012b). *Informing research choices: Indicators and judgment*. Ottawa: CCA.

---. (2006). *The state of science and technology in Canada, 2006*. Ottawa: CCA.

Council of Ministers of Education, Canada (CMEC). (1997). *Common framework of science learning outcomes, K to 12: Pan-Canadian protocol for collaboration on school curriculum*. Toronto: CMEC.

Dufour, P. (2010). Supplying demand for Canada's knowledge society: A warmer future for a cold climate? *American Behavioural Scientist*, *53*(7), 983-996.

Fast, E. (2007). *Mobilizing science and technology: A new federal strategy*. Ottawa: Library of Parliament.

Fisher, D., Atkinson-Grosjean, J., & House, D. (2001). *Changes in academy/industry/state relations in Canada: the creation and development of the networks of centres of excellence*. *Minerva, 39*, 299–325.

Fisher, D., Rubenson, K., Bernatchez, J., Clift, R., Jones, G., Lee, J., MacIvor, M., Meredith, J., Shanahan, T., & Trottier, C. (2006). *Canadian Federal Policy and Postsecondary Education.* Vancouver: Centre for Policy Studies on Higher Education and Training, University of British Columbia.

Fisher, D., Rubenson, K., Jones, G., & Shanahan, T. (2009). The political economic of post-secondary education: a comparison of British Columbia, Ontario and Quebec. *Higher Education*, *57*, 549-566.

Genome Canada. (2011). *Genome Canada Annual Report 2011-2012.* Ottawa: GC.

KPMG. (2009). *Evaluation of Genome Canada – Final Report*. Ottawa: KPMG.

Government of Canada (Science, Technology and Innovation Council). (2011). *State of the Nation 2010: Canada's Science, Technology and Innovation System*. Ottawa: Government of Canada.

---. (2009). *State of the Nation 2008: Canada's Science, Technology and Innovation System*. Ottawa: Government of Canada.

Government of Ontario. (2008a). *The Ontario curriculum Grades 9 and 10: Science*. Toronto: Government of Ontario.

Government of Ontario. (2008b). *The Ontario curriculum Grades 11 and 12: Science*. Toronto: Government of Ontario.

---. (2007). *The Ontario curriculum Grades 1-8: Science*. Toronto: Government of Ontario.

Human Resources and Skills Development Canada. (2008). *Looking-ahead: A 10-year outlook for the Canadian labour market (2008-2017)*. Ottawa: HRSDC.

Industry Canada. (2012). Canadian Science and Technology Data – 2010. Ottawa: Industry Canada.

---. (2009). *Mobilizing science and technology to Canada's advantage: Progress Report*. Ottawa: Industry Canada.

---. (2007). *Mobilizing science and technology to Canada's advantage*. Ottawa: Industry

Canada.

Jones, G. A. (2006). Canada. In J. J. F. Forest and Philip G. Altbach (Eds.), *International Handbook of Higher Education* (pp. 627-645). Dordrecht, The Netherlands: Springer.

Knighton, T., Brochu, P., & Gluzynski, T. (2010). *Measuring up: Canadian results from the OECD PISA study.* Ottawa: Ministry of Industry.

Let's Talk Science. (2010a). Parent attitudes towards science education. Retrieved from http://www.letstalkscience.ca/images/stories/Research/Science%20Education%20Campaign%20-%20Survey%20Results.pdf

---. (2010b). Teen attitudes towards science education. Retrieved from http://www.letstalkscience.ca/images/stories/Research/Science%20Education%20Media%20Campaign%20Backgrounder_FINAL.pdf

McKenzie, M. (2007). *Science and Engineering PhDs: A Canadian Portrait*. Ottawa: Statistics Canada.

Metcalfe, A., & Fenwick, T. (2009). Knowledge for whose society?: knowledge production, higher education, and federal policy in Canada. *Higher Education*, 57, 209-25.

Milford, T., Jagger, S., Yore, L., & Anderson, J. (2010). National influences on science education reform in Canada. *Canadian Journal of Science, Mathematics and Technology Education*, *10*(4), 370-381.

Mishigina, N. (2012). *The state of STEM labour markets in Canada: Literature review*. Montreal: Cetnre interuniversitaire de research en analyse des organisations.

Mendelson, M. (2006). *Aboriginal Peoples and Postsecondary Education in Canada*. Ottawa: Caledon Institute of Social Policy.

Networks of Centres of Excellence. (2011). Industrial Research and Development Internship (IDRI): Program Guide. Ottawa: Government of Canada. Retrieved from http://www.nce-rce.gc.ca/_docs/competitions/IRDICompetition-ConcoursSRDI/ProgramGuide-GuideProgramme_eng.pdf

OECD. (2012a). *Education at a Glance 2012*. Paris: OECD.

---. (2012b). *Tertiary education: Developing skills for innovation and long-term growth in Canada*. Paris: OECD.

---. (2012c). *OECD Economic Surveys: Canada 2012*. Paris: OECD.

---. (2011a). *Education at a Glance 2011*. Paris: OECD.

---. (2011b). *Main Science and Technology Indicators, 2011/12*. Paris: OECD.

---. (2010). *Pathways to success: How knowledge and skills at age 15 shape future lives in Canada*. Paris: OECD.

Orpwood, G., Schmidt, B., & Jun, H. (2012). *Competing in the 21st century skills race*. Ottawa: Canadian Council of Chief Executives (CCCF).

Prism Economics and Analysis. (2009). *Right for Me? A study of factors that shape the attitude of young women towards mathematics and science and towards careers in engineering and technology.* Toronto: Prism Economics and Analysis.

Sa, C. (2010). Canadian provinces and public policies in university research. *Higher Education Policy*, *23*, 335-357.

Salazar, M., & Holbrook, A. (2007). Canadian science, technology and innovation policy: the product of regional networking? *Regional Studies*, *41*(8), 1129-1141.

Science Metrix. (2010). *Tenth-Year evaluation of the Canada Research Chairs Program*. Retrieved from http://www.chairs-chaires.gc.ca/about_us-a_notre_sujet/publications/ten_year_evaluation_e.pdf

Shanahan, T., & Jones, G. A. (2007). Shifting roles and approaches: government coordination of post-secondary education in Canada, 1995-2006. *Higher Education Research and Development, 26*(1), 31-43.

Statistics Canada. (2012). *Education indicators in Canada: An international perspective*. Ottawa: Statistics Canada. Catalogue number - 81-604-X.

---. (2011a). *Education indicators in Canada: An international perspective*. Ottawa:

Statistics Canada. Catalogue number - 81-604-X.

---. (2008). *Educational Portrait of Canada, 2006 Census*. Ottawa: Canada. Catalogue number - 97-560-X.

---. (n.d). *National Graduate Survey (Class of 2005, 2000) - Table A.15 - Unemployment rate by field of study, Ontario and Canada without Ontario*. Ottawa: Statistics Canada. Retrieved from http://www.statcan.gc.ca/pub/81-595-m/2012098/tbl/tbla.15-eng.htm

Walters, D., & Frank, K. (2010). *Exploring the alignment between postsecondary education programs and labour market outcomes in Ontario*. Toronto: Higher Education Quality Council of Ontario.