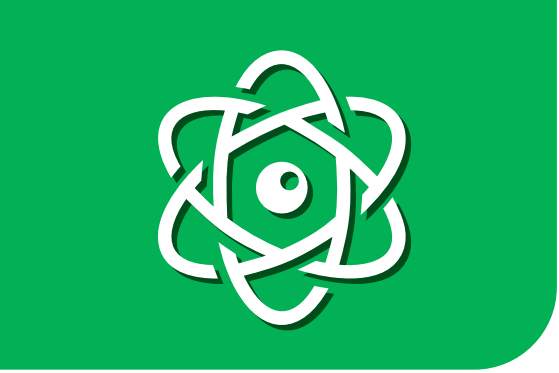
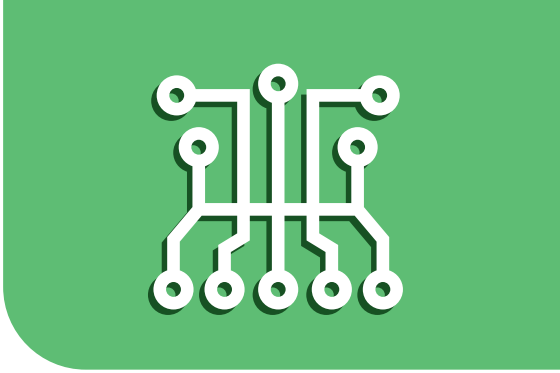

Some Assembly Required: STEM Skills and Canada's Economic Productivity

Executive Summary

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

SOME ASSEMBLY REQUIRED: STEM SKILLS AND CANADA'S ECONOMIC PRODUCTIVITY

The Expert Panel on STEM Skills for the Future

THE COUNCIL OF CANADIAN ACADEMIES
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Science Advice in the Public Interest

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Message from the Chair

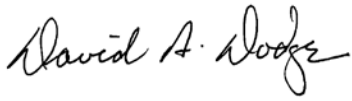
Canada has one of the most highly trained workforces in the world. The skills and abilities of Canadians have played a key part in ensuring that Canada has one of the highest standards of living in the world. Maintaining and developing Canada's strength in this regard is a central pillar of our future prosperity.

However, many new challenges are on the horizon — or already upon us. They include the rapid pace of technological change, an aging population, environmental concerns associated with increased resource extraction, and rapid growth of developing economies with large numbers of capable students. In this evolving global context, Canada must ensure that its workforce has the right balance of skills to take advantage of opportunities and be prepared to adapt to change.

An array of skills and assets are important, including those related to the arts and humanities, mathematics, social sciences, and natural and life sciences. We were asked to examine a particular set of skills: science, technology, engineering and mathematics (STEM) skills. STEM skills have been advanced as central to innovation and productivity growth, which are in turn necessary for improving standards of living. While the general reasons behind this logic are clear, the Panel had difficulty finding direct and robust evidence that STEM skills are unique in this regard. However, productivity growth is also about working smarter. The fundamental skills required for STEM literacy, such as problem solving, technological proficiency, and numeracy, represent essential components of working smarter. They are the building blocks of more advanced and specialized STEM skills, and they remain useful regardless of whether or not individuals choose STEM careers. Indeed, we found that these skills open doors to a range of education and employment options, and are thus vital for all Canadians.

After 18 months of study, we are convinced that high-quality investments in STEM skills — in both early education and in more advanced training — are critical to Canada's prosperity. Beyond preparing students and the labour force for a range of future possibilities, these investments appear to be one of several components required to improve Canada's poor innovation and productivity record.

To my colleagues on the Panel: thank you for your collaboration and dedication to this topic. Together, we thank Employment and Social Development Canada for sponsoring this study, and the staff at the Council of Canadian Academies for ably supporting us through the assessment process. We also appreciate the input of the 11 external reviewers who volunteered their time to critique an earlier version of this report.



David Dodge, O.C., FRSC
Chair, Expert Panel on STEM Skills for the Future

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Report Review

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Council of Canadian Academies for their diverse perspectives, areas of expertise, and broad representation of academic, industrial, policy, and non-governmental organizations. The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the authoring Panel and the Council. The Council wishes to thank the following individuals for their review of this report:

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The report review procedure was monitored on behalf of the Council's Board of Governors and Scientific Advisory Committee by **William R. Pulleyblank**, Professor of Operations Research, Department of Mathematical Sciences, US Military Academy (West Point, NY). The role of the Report Review Monitor is to ensure that the Panel gives full and fair consideration to the submissions of the report reviewers. The Board of the Council authorizes public release of an expert panel report only after the Report Review Monitor confirms that the Council's report review requirements have been satisfied. The Council thanks Professor Pulleyblank for his diligent contribution as Report Review Monitor.

Executive Summary

It is generally understood that skills make critical contributions to Canada's prosperity. However, there is uncertainty about precisely which skills are needed to thrive in tomorrow's economy, how skills directly contribute to innovation and productivity, whether some skills are more connected to these goals than others, and whether there is an optimal combination of skills that fosters growth. Many skills are required to advance human knowledge and social and economic development. However, in a complex and uncertain global economy, science, technology, engineering, and mathematics (STEM) skills are in the spotlight, as countries aim to maximize their economic competitiveness and productivity. As a result, governments, policy-makers, educators, and business leaders are particularly concerned about how well equipped Canada is with the STEM skills needed to fulfil labour market demands and promote innovation.

To gain the information required to make optimal investments in STEM skills, education, training, and labour force development in Canada, Employment and Social Development Canada asked the Council of Canadian Academies (the Council) the following question:

How well is Canada prepared to meet future skill requirements in science, technology, engineering and mathematics (STEM)?

Additional direction was provided through four sub-questions:

- *What role do STEM skills play in supporting and fostering innovation, productivity, and growth?*
- *What is the extent and nature of the global market for STEM skills and how does it interact with the Canadian market?*
- *How is labour market demand for STEM skills likely to evolve in the future? Which STEM skills are likely to be most in demand?*
- *What is known about the relative importance of different factors affecting Canada's supply of STEM skills, especially through the Canadian learning system and international migration?*

To address the charge, the Council appointed a multidisciplinary expert panel (the Panel) with a range of experience, expertise, and leadership in areas relevant to the charge, including economics, human resources, university and college administration, business, and STEM professions. In preparing its

report, the Panel drew from two main sources of evidence: a comprehensive literature review and a new analysis of educational and occupational data on STEM skills. The Panel's findings represent its collective judgment based on its review of the best available evidence.

SUMMARY STATEMENT

Overall the Panel found no evidence of a current imbalance between the demand for and supply of STEM skills at the national labour market level. It also found insufficient direct evidence on the exact nature and impact of STEM skills on innovation and productivity growth. These findings suggest that the source of Canada's productivity problem is not a shortage of advanced STEM skills. Short-term, localized imbalances may exist, but the Panel emphasized the importance of focusing on long-term economic outcomes. Long-term projections on the need for specialized skills are highly difficult to undertake, especially considering rapid and inevitable changes in technology, economy, and society. As a result, it was not possible to definitively determine the skills and knowledge required for the jobs of the future.

However, it is clear that STEM skills are central to a variety of education and job opportunities. They provide individuals with options in uncertain labour markets. While maintaining Canada's advanced STEM skills capacity is important, investments in STEM literacy are crucial for developing a skilled society that is prepared to respond to an uncertain future. Increasing the quality and level of fundamental skills for STEM among all learners at the preschool, primary, and secondary education levels represents a strategic, long-term approach towards this goal. Such investments may also help to improve Canada's levels of innovation and productivity.

MAIN FINDINGS

It is not possible to definitively determine what skills and knowledge will be required for the jobs of the future. Proactive, long-term strategies to keep a range of economic options open include investments in building fundamental STEM skills while maintaining Canada's capacity for producing advanced STEM skills.

Long-term labour market demands are difficult to predict. A range of external forces influence the economy, including constant changes in technology and the increased capacity for automation. These forces can profoundly alter the nature of work. Nonetheless, STEM skills are central to a variety of education and job options. They equip individuals with essential tools that are required to adjust to change, which is a benefit considering future labour market

uncertainties. Thus, long-term sustained investments in fundamental skills for STEM literacy in Canada represent a sensible response to growing uncertainty about the future of technology, the changing nature of work, and expected demands for skills. At the level of advanced STEM skills development, dedicated assets remain important for basic research.

To build this capacity and maximize Canada's potential for innovation, evidence points to the value of early childhood interventions to strengthen fundamental skills.

Results from standardized tests demonstrate that Canadian youth perform relatively well in science and mathematics-related domains. However, there remains significant room for improvement to increase the level of fundamental skills among all learners, as well as to grow the talent pool of top performers. High-quality interventions, in pre-primary education through to secondary school, are a significant factor in both of these endeavours. While there are many types of fundamental skills, STEM education provides a rich environment for developing some of them, including mathematics, computational facility, reasoning, and problem solving. These skills form the basis for more advanced STEM skills. As a result, fundamental skills for STEM are important for all Canadians, regardless of occupation. Beyond preparing students for a range of future possibilities, the Panel emphasized the urgency of the opportunity to invest in fundamental STEM skill building, suggesting that early investments may be one of a suite of components required to reverse Canada's poor innovation record.

There is no evidence of a current imbalance of advanced STEM skills nationally.

Canada appears to have a well-functioning labour market, where individuals are choosing fields of study and occupations based on factors such as market signals and personal preferences. This conclusion is based on a number of indicators, including employment and unemployment data, wages, and STEM education and occupation matching. Although smaller-scale mismatches by industry and region may exist, they are difficult to assess with available data. For example, compared with other provinces, earnings in Alberta are generally higher and have increased faster for STEM *and* non-STEM graduates, suggesting growing demand for skills and difficulty finding an adequate supply of educated workers in general. In other words, these signals are not unique to STEM graduates. Such a tight labour market is consistent with a fast-growing economy, rather than a shortage of particular skills.

Long-term economic outcomes matter.

While short-term, localized imbalances may be challenging, the Panel agreed that focusing on long-term economic outcomes is important. The Panel cautions that a focus on narrowly specialized STEM skills development to meet short-term labour market requirements may have little relevance for meeting long-term skill requirements. Short-term labour requirements in certain industries may quickly shift (e.g., the dotcom bust). New technologies are also creating industries and occupations that previously did not exist. Under normal market conditions, investing heavily in specialized training has significant risks for individuals and society: changes in demand for niche skills over time may result in obsolete or undervalued skills, and deep investments in one area come at the cost of not investing in other skills. Although dedicated assets are important for basic research, as well as development of new innovations, targeted labour market interventions to increase the number of STEM-skilled workers should not be required in a well-functioning, self-regulating economy.

STEM skills are necessary but not sufficient for innovation and productivity growth.

While the theoretical reasons for a link between STEM skills and innovation are clear, there is currently limited evidence on the specific contribution of advanced STEM skills to productivity growth, or the magnitude of these effects. The only clear evidence of the impact of STEM on innovation and productivity comes from a few preliminary studies. These suggest that STEM-skilled immigrants have a patenting advantage and regionally generate significant and positive wage increases for non-STEM, university-educated Canadian workers.

Other evidence suggests that more assets than STEM skills alone are required for productivity growth. First, there are many types of innovation, and not all of them depend on STEM skills. Complementary skills, such as communication, teamwork, and leadership, are also important in and of themselves, as well as to maximize the impact of STEM skills. Second, wages are one indicator of labour productivity. At first glance, STEM graduates appear to command higher wages than their non-STEM counterparts. A closer look reveals enough variation (by gender, level of education, immigration status, and STEM field) to call the accuracy of the commonly cited "STEM wage premium" into question. Third, since evidence on a current imbalance of STEM skills nationally is lacking, the Panel agreed that the source of Canada's productivity problem is not a shortage of specialized STEM skills. As documented in other Council reports, demand-side issues cannot be solved with supply-side solutions.

In the Panel's view, the balance of evidence on the impact of STEM skills on innovation suggests that they generate meaningful benefits, leading to their judgment that STEM skills represent an important but not sufficient condition for innovation, productivity, and economic growth.

Support for under-represented populations in STEM is important for broadening Canada's STEM skill supply.

Canada is currently missing out on an important supply of skilled talent. Increasing the STEM participation of under-represented populations, including women and Aboriginal peoples, is an important strategy for diversifying the supply of STEM-skilled individuals. Just 29.6% of individuals with a post-secondary STEM credential and 26.9% of those employed in a STEM-intensive occupation in Canada are women. Increasing high school completion rates and post-secondary attainment among Aboriginal populations remains important. The implications of these serious disparities are costly for society, the economy, science, and innovation. By attracting individuals with diverse perspectives, experiences, and ideas, a wider talent pool can reveal deeper assets.

STEM skills are global skills.

STEM skills are globally transferable. In contrast to concerns throughout the 1990s about brain drain, data indicate that the emigration of STEM-skilled Canadians is more than offset by STEM-skilled immigrants, through a process known as *brain circulation*. Though immigrants account for 21% of Canada's population, they are a major source of STEM skills, representing around 50% of all STEM degree-holders in Canada at the bachelor's level and above. However, immigrants can experience difficulties connecting with the Canadian labour market, as demonstrated by their higher unemployment rates and lower employment rates compared with workers born in Canada. These outcomes have negative implications for individuals and Canada as a whole.

Beyond facilitating the presence of individuals with new knowledge and skills through immigration, bidirectional flows of skilled labour increase international connections: networks can accelerate the globalization of labour markets and open new opportunities for trade, investment, and entrepreneurship. Canada can draw on the global pool for highly advanced and specialized technical experts when the domestic capacity for niche STEM skills does not meet demand. However, it is less optimal to draw on temporary international labour to meet demand for skills in broad occupational categories. It may diminish the incentive for firms to train and develop employees' skill sets, as

well as discourage individuals from investing in their own skills development. The Panel concluded that the long-term benefits of immigration are more important than the short-term goal of access to temporary labour.

Developing a flexible labour force requires collective, coordinated action to facilitate education, training, and mobility.

Flexibility in a range of education and training systems, including universities, colleges, polytechnics, employer-based training, and government programs, is required to help equip the next generation of learners with the STEM skills that they need as workers, and as members of society. Collaboration and coordination among post-secondary institutions, government, industry, and community organizations in Canada are important to enable a range of options, skills, and ongoing learning opportunities for individuals.

STEM SKILLS FOR THE FUTURE

The global economy is experiencing accelerated transitions. Major advances in information and communication technologies, nanotechnology, and genomics are changing businesses, society, and lives. An aging population and a shrinking labour force are driving demographic shifts in Canada. Declining growth in industrialized economies (including in Canada's major trading partner, the United States) and the emergence of new markets are shifting the concentration of export opportunities and import competition. The increasing global demand for energy is driving major environmental challenges. Against the backdrop of unstable energy prices, governments and enterprises are being challenged to become innovation leaders. At the same time, Canada is still striving to improve its poor productivity record. In many ways, these challenges and opportunities are linked to science and technology. In some cases, these links are clearer than in others. In the Panel's view, STEM skills are necessary for many types of innovation, as well as productivity and growth, but they are not sufficient on their own. Other skills such as leadership, creativity, adaptability, and entrepreneurial ability may be required to maximize the impact of STEM skills. Further, the Panel did not find evidence of a current imbalance in advanced STEM skills nationally, suggesting that the source of Canada's productivity problem is not a shortage of advanced STEM skills.

This finding does not diminish the critical importance of STEM skills to Canada and Canadians. STEM benefits society in many ways, from breakthrough drugs to safe structures, more efficient and sustainable forms of transportation, convenient apps, and innovative forms of workplace organization. Maintaining

Canada's capacity for producing advanced STEM skills, while finding new ways to foster demand for these skills through business innovation, remains essential for sustaining and improving our quality of life.

Given the inherent uncertainty of the future, one of the most proactive and strategic ways to be prepared in the long term is to ensure that Canadians have a strong base of fundamental skills. The fundamental skills that enable STEM literacy are prerequisites for a variety of education and career pathways. Such skills will equip individuals and the economy with the flexibility to take advantage of a number of opportunities, and increase the range of options available. Investments at the pre-primary through to secondary school levels are important to develop a STEM-literate society with strong fundamental skills. This action may be an important step towards improving Canada's poor innovation record.