INSTITUT C.D. HOWE INSTITUTE

COMMENTARY
NO. 626

The Knowledge Gap: Canada Faces a Shortage in Digital and STEM Skills

Demand for employees with basic or advanced digital skills has been growing rapidly in Canada, but a swath of industries face shortages in meeting their needs. Governments should take several steps to close the gap, including reforms to immigration policy.

Parisa Mahboubi

About The Author

Parisa Mahboubi
is a Senior Policy Analyst at the C.D. Howe Institute.

The C.D. Howe Institute's Commitment to Quality, Independence and Nonpartisanship

The C.D. Howe Institute's reputation for quality, integrity and nonpartisanship is its chief asset.

Its books, Commentaries and E-Briefs undergo a rigorous two-stage review by internal staff, and by outside academics and independent experts. The Institute publishes only studies that meet its standards for analytical soundness, factual accuracy and policy relevance. It subjects its review and publication process to an annual audit by external experts.

As a registered Canadian charity, the C.D. Howe Institute accepts donations to further its mission from individuals, private and public organizations, and charitable foundations. It accepts no donation that stipulates a predetermined result or otherwise inhibits the independence of its staff and authors. The Institute requires that its authors disclose any actual or potential conflicts of interest of which they are aware. Institute staff members are subject to a strict conflict of interest policy.

C.D. Howe Institute staff and authors provide policy research and commentary on a non-exclusive basis. No Institute publication or statement will endorse any political party, elected official or candidate for elected office. The views expressed are those of the author. The Institute does not take corporate positions on policy matters.

Commentary No. 626
August 2022

Daniel Schwanen
Vice President, Research

$12.00
ISBN 978-1-989483-89-3
ISSN 0824-8001 (print);
ISSN 1703-0765 (online)

The Study In Brief

Due to rapid digitalization across the economy and an aging population, Canada faces digital and STEM skills shortages. The COVID-19 pandemic has also intensified the need for digital and STEM skills and contributed to the existing shortages. These skills shortages can hurt businesses and affect economic growth.

To respond, Canada needs to increase its supply of people with digital skills by developing and attracting digital talent and to investing in the reskilling and upskilling of its workforce.

To attract more digital talent and to make immigration a tool for capturing opportunities in the digital economy, the federal and provincial governments should reform immigration programs to increase the admission of immigrants with prior study-permit-holder status and retain international students, particularly in STEM fields; ensure that the combined temporary and permanent immigration programs sufficiently increase the supply of newcomers with digital skills and that skilled immigrants receive the tailored support they need to integrate successfully into the labour market; and reduce the underemployment of skilled immigrants through greater efforts to bolster language skills and address barriers to the recognition of foreign credentials and experience.

To develop digital talent, governments at all levels, according to their responsibilities, should take a holistic approach, including:

- reforming the education system, ensuring availability of resources and training options for teachers to implement modernized curricula;
- increasing STEM enrolment and graduation numbers by raising students' performance in STEM subjects, closing the STEM gender divide by better helping students to make study and career choices and encouraging under-represented groups to continue their education in STEM fields by identifying and addressing their particular needs;
- working with educational institutions to develop and expand digital skills learning, artificial intelligence (AI) and data science courses and programs;
- increasing high-quality work experience options such as work-integrated learning (WIL) opportunities and expanding co-op programs in the information and communications technology (ICT) sector;
- investing in micro-credential/certification programs that are paired with work placement for youth not in education, employment or training;
- investing in upskilling and reskilling the existing workforce; and,
- preventing brain drain and retaining new graduates.

Finally, employers should also take actions to expand the pool of digital talent and address their digital skills needs. They need to offer higher wages to attract more workers, provide on-the-job training opportunities to address skills gaps, shift their focus from degrees to skills and recognize and support non-formal training options.

Policy Area: Education, Skills and Labour Market.
Related Topics: Human Capital, Skills, Occupational Choice, Labor Productivity.
To cite this document: Mahboubi, Parisa. 2022. *The Knowledge Gap: Canada Faces a Shortage in Digital and STEM Skills.* Commentary 626. Toronto: C.D. Howe Institute.

To order this publication please contact: the C.D. Howe Institute, 67 Yonge St., Suite 300, Toronto, Ontario M5E 1J8. The full text of this publication is also available on the Institute's website at www.cdhowe.org.

Technological developments have significantly changed digital skills needs in the workplace. In addition, an aging population, increasing global competition and strong demand for workers in the digital economy[1] have led to shortages of workers trained in science, technology, engineering and mathematics (STEM), as well as in digital skills (Information Technology Association of Canada 2016; Statistics Canada 2021).

The COVID-19 pandemic has also intensified the use of technology, accelerating previous trends and contributing to the already fast-growing role of the digital economy, since it has affected the way businesses operate and how people work and live. Consequently, digital and data skills are increasingly required across all sectors of the global economy including in Canada.

The pace of digitalization depends, however, on other factors, including digital skills and talent gaps (World Economic Forum 2020). These gaps occur when there is an imbalance between the digital skills the workforce possesses and the skills employers need, making employers unable to find candidates with the required skills to fill vacant positions. If they are not addressed, skills shortages can hurt businesses and affect economic growth.

This *Commentary* shows digital skills needs and shortages in the Canadian labour market, analyzes contributing factors to the supply of digital skills and offers policy recommendations on how to bridge the digital skills gaps through developing, attracting and retaining digital talent. It highlights the important role of education and training as well as immigration in addressing shortages.

With a record low unemployment rate in June 2022 (4.9 percent) and rising demand for digital skills, Canada's labour market is becoming tighter amid growing concern over shortages.[2] To address these shortages, the supply of digital skills can come from new graduates, newcomers, labour market and career transitioners, discouraged workers and out-of-workforce people.

Already, various immigration programs at the federal and provincial levels aim to attract global talent, permanently or temporarily. Ontario, Alberta and British Columbia recently introduced pilot immigration programs specifically for tech

The author thanks Rosalie Wyonch, Charles DeLand, Mawakina Bafale, Paul Fogolin, Troy Pariag, and Alex Usher for comments on an earlier draft. The author retains responsibility for any errors and the views expressed.

1 According to reports by the Information and Communications Technology Council (ICTC), the digital economy includes all workers (either tech or non-tech workers) in the tech sector as well as all tech workers in all other sectors of the economy (Ivus and Kotak 2021).

2 Although the tech sector recently witnessed some layoffs, it would be a mistake to assume that digital skills shortages have disappeared. Many of these workers faced short-term unemployment and were hired by other employers (Deschamps 2022b) since the need for digital skills is not concentrated in one industry anymore.

Key Concept Explainer

Digital Skills:

Digital skills for work include a broad spectrum that enable workers to find, use, design, develop and share digital content, and to communicate and collaborate using digital devices to solve problems more effectively. Broadly speaking, workplace digital skills can range from basic skills required of the general workforce, to specialized and advanced digital skills needed for developing digital technologies, products and services.

Basic digital skills can include computer literacy, data entry, storing and managing data, social media, web-based communications and research, word processing and secure information processing. These basic digital skills enable individuals to work in jobs that require the ability to carry out tasks such as communicating via email, participating on social media, researching information online, creating and managing spreadsheets and online documents, organizing and screen sharing during virtual meetings, updating and keeping passwords secure.

Advanced digital skills can include coding and programming, web and app development, digital business analysis, digital marketing and content creation, digital design and data visualization, digital product management, computer and data science and user experience design. Formal post-secondary education in a STEM field of study is often required to obtain advanced digital skills. Examples of occupations that require advanced digital skills are hardware engineer, software developer and engineer, computer scientist, computer systems analyst, data designer, programmer, information systems technician and IT assistant.

professionals to meet their digital skills needs. The federal and provincial governments could do more, however, to make immigration a tool for capturing opportunities in the digital economy; for example, they could reform immigration programs to increase the admission of immigrants with prior study-permit-holder status, particularly in STEM fields, to increase retention. The federal government should also ensure that the combined temporary and permanent immigration programs sufficiently increase the supply of newcomers with digital skills and that skilled immigrants receive the tailored support they need to integrate successfully into the labour market and to eliminate the underemployment of skilled immigrants. This would require greater efforts to bolster language skills and address barriers to the recognition of foreign credentials and experience.

Governments at all levels, according to their responsibilities, should continue to support the development of domestic talent. This would require a holistic approach, including:

- reforming the education system, ensuring the availability of resources and training options for teachers to implement modernized curricula;
- increasing STEM enrolment and graduation numbers by raising students' performance in STEM subjects, closing the STEM gender divide by better helping students to make study and career choices and encouraging under-represented groups to continue their education in STEM fields by identifying and addressing their particular needs;
- working with educational institutions to develop and expand digital skills learning, artificial intelligence (AI) and data science courses and programs;

- increasing high-quality work experience options such as work-integrated learning (WIL) opportunities and expanding co-op programs in the information and communications technology (ICT) sector;
- investing in micro-credential/certification programs that are paired with work placement for youth not in education, employment or training;
- investing in upskilling and reskilling the existing workforce; and,
- preventing brain drain and retaining new graduates.

Employers also need to offer higher wages to attract workers and compete with foreign employers, offer on-the-job training opportunities to address skills gaps, shift their focus from degrees to skills and recognize and support non-formal training options to expand the pool of digital talent.

Digital and STEM Skills Needs and Shortages

To identify digital skills needs and shortages in the labour market, the first step is to define and categorize digital skills, as there are significant variations in skills needs across sectors and occupations. Workplace digital skills include a broad spectrum that enable workers to design, develop and share digital content, and to communicate and collaborate using digital devices to solve problems more effectively. Broadly speaking, digital skills can range from basic skills required of the general workforce to use digital technologies and applications and to process information, to more specialized and advanced digital skills needed for developing digital technologies, products and services (see Key Concept Explainer). Formal postsecondary education is often required to obtain advanced digital skills. Naturally, employers consider graduates in some specific STEM fields for more professional and specialized digital roles, since, although digital and STEM skills are not identical, they overlap in many ways: STEM skills include those needed to do science, mathematics and engineering, as well as to use technology effectively.[3]

An industry that requires STEM and digital skills extensively is the professional, scientific and technical services industry. Employment in this industry has grown faster than in other industries: by 79 percent in 2021 relative to 2000, and between 2020 and 2021 it had its largest year-over-year increase (9.5 percent), well above its average annual rate of 2.6 percent over the past two decades. It has also contributed to employment growth in the ICT sector:[4] in 2019, 40 percent of ICT workers were employed in professional, scientific and technical services (ICTC 2020).

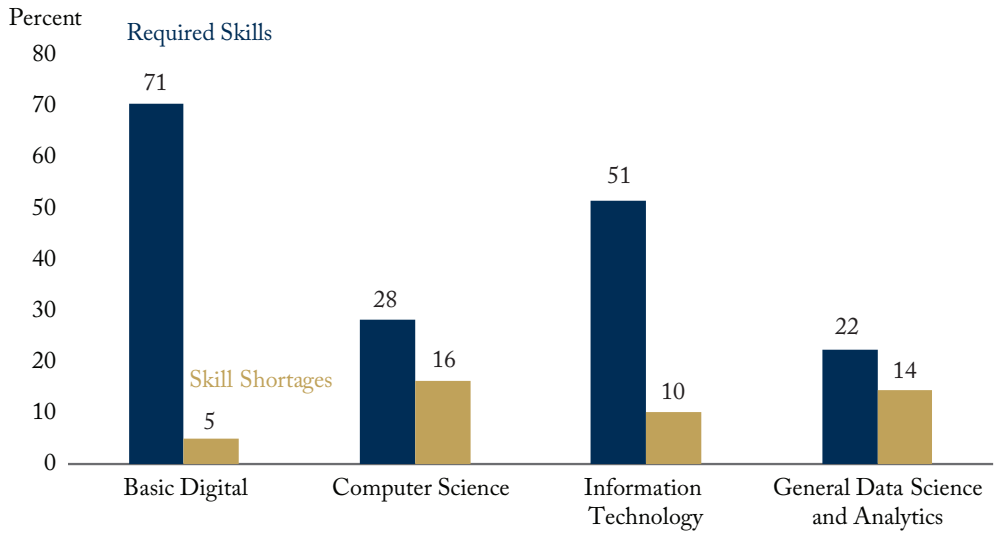
Evidence prior to the pandemic points to a STEM skills shortage in Canada (Randstad (2015), and shows that, in addition to the ICT sector, employers in other industries, such as financial services, manufacturing, healthcare and the public sector, face digital skills shortages (Shortt, Robson, and Sabat 2020). Furthermore, about 20 percent of pre-pandemic employment was at high risk of automation, which could contribute to future digital skills shortages (Wyonch 2020a), since it would increase demand for both basic and specialized digital skills (Bughin et al. 2018; Feijao et al. 2021).

According to Statistics Canada's 2019 Survey of Innovation and Business Strategy, employers' digital skills needs and shortages significantly vary by type of skills (Figure 1). Most employers in 2019 needed basic skills and only a small percentage of businesses had difficulty meeting those needs. In contrast,

3 Examples of STEM skills are analysis, problem solving, creativity, math, computers and technology and design thinking.

4 The ICT sector comprises certain manufacturing sub-industries and services sub-industries, including professional, scientific and technical services.

Figure 1: Required Skills and Skill Shortages by Type among Canadian Businesses, 2019



Notes: The population of businesses for skills shortages is made up of businesses that required at least one type of skill (regardless of it being a digital skill or not) and encountered a skill shortage. Examples of basic skills are email, word processing, and spreadsheets. Computer science includes software engineering and artificial intelligence. Information Technology includes IT security, database administration. General data science and analytics include data modeling and visualization.

Source: Statistics Canada, Survey of Innovation and Business Strategy, Tables 33-10-0299-01 and 33-10-0300-01.

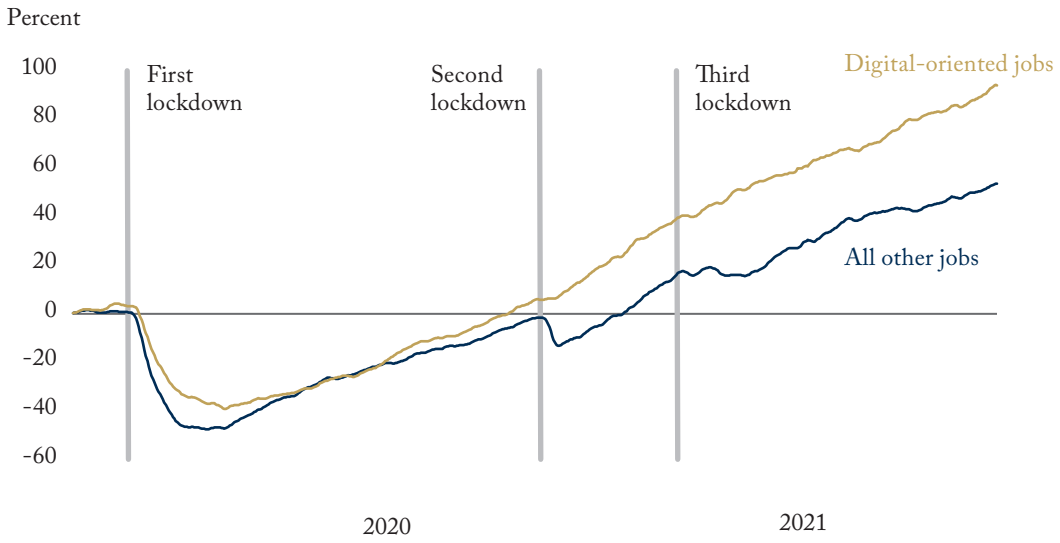
only 28 percent and 22 percent of employers were in need of computer science skills and general data science and analytical skills, respectively, but 16 percent and 14 percent of firms reported a skills shortage in these two specialized digital skills. Shortages varied significantly across sectors – for example, 62 percent of employers in the scientific research and development services industry needed computer science skills, but about 50 percent of employers had difficulty meeting these needs.

Although the share of employers facing a specialized and advanced digital skills shortage is relatively small compared to all employers experiencing a skills shortage, extensive shortages within particular industries are problematic, for two reasons. First, these shortages are more difficult to address since it is harder and more time consuming to acquire specialized digital skills. Second, widespread skills shortages within an industry can affect its growth – for example, digital skills shortages have limited growth in the video game industry, a rapidly growing industry in Canada that requires highly trained software engineers and programmers (Beauplat 2021; ESAC 2021; Massé 2021).

It is hard to assess precisely the extent of digital skills shortages in Canada since the start of the pandemic, given insufficient data and labour market information. However, available sources and information on job postings, employment, job vacancies and unemployment by industry and occupation can help to gauge recent trends.

According to Indeed's Canadian job postings, demand for digital and data skills has been growing swiftly not only in digital-oriented occupations, but also in all other jobs (Figure 2). Despite the challenges small and medium-sized

Figure 2: Growth in Employers' Demand for Digital Skills, February 2020-November 2021



Notes: Digital-oriented jobs are linked to the production of digital technology including software, hardware and information technology support. The figure shows the seasonally adjusted percent change in Canadian job postings since Feb-01, 2020 (7-day moving average).

Consistent with Bellatin and Galassi (2021), the first, second and third lockdowns, respectively, started on March 12, 2020, December 26, 2020, and April 1, 2021.

Source: Indeed job posting data.

employers (SMEs) face in accessing and adapting technologies, a survey conducted by the Canadian Federation of Independent Business also shows that 26 percent of SMEs' owners were able to go digital by May 2020 – only a few months into the pandemic (Saba and Blanchette 2020). Therefore, it is not surprising that the demand for digital skills has been accelerating across all types of businesses and jobs.

Employment in the digital economy has also outperformed all other sectors in Canada in terms of employment recovery, at more than 16 percent higher in September 2021 than the pre-pandemic level (February 2020) (ICTC monthly Infographics). At the time, there were 2.19 million workers in the digital economy, with tech workers in non-ICT sectors the largest- and fastest-growing component (51.8 percent), compared with tech workers in the ICT sector (28.6 percent) and non-tech workers in the ICT sector (19.6 percent). These figures, coupled with low unemployment rates among ICT professionals[5] and in professional, scientific and technical services – 2.0 percent in May 2022, compared with the overall unemployment rate of 5.2 percent – and increased job vacancies in these industries all suggest

5 The unemployment rate among ICT professionals in September 2021 was 2 percent – 4.9 percentage points below the national unemployment rate.

that existing digital skills shortages might have worsened and that the shortages are more likely to be related to the quantity of potential candidates than the quality, given a very low unemployment rate. According to the president of the Council of Canadian Innovators, there were more than 200,000 vacant tech positions in Canada as of March 2022 (Deschamps 2022).

In a tight labour market with high job vacancies and a low unemployment rate, employers might need to offer higher wages to attract workers. Surprisingly, however, high digital job vacancies and labour shortages in Canada have not led to a strong growth in offered wages. Job vacancies for computer and information systems professionals, for example, increased by more than 77 percent between the fourth quarter of 2020 and the fourth quarter of 2021 (Statistics Canada 2022b), while the average hourly offered wage for vacant positions grew by 4.6 percent, not even keeping up with inflation. It is worth mentioning that increases in offered wages are effective only in the short term if there is sufficient supply of labour with the right skills, but they can create an incentive for increasing the supply of digital skills in the future. In that regard, Canadian employers predict that digital skills such as cognitive computing, cybersecurity, general IT, and computer science will continue to be in demand in the future, and the most pressing skills shortages over the next few years will be in these areas, according to a survey of employers conducted by Business Council of Canada (2022).

Domestic Sources of Digital Skills

Domestic sources of digital skills supply include new graduates and the current working-age population. Table 1 shows that the number of enrolments in STEM fields grew significantly faster than that in non-STEM fields and in overall postsecondary enrolments between 2010 and 2019. As a result, the share of STEM enrolment in Canada went up by about 5.4 percentage points during the same period, reaching 25 percent in 2019 – likely due in part to efforts to increase enrolment in STEM disciplines. Within STEM, science and science technology has been the most popular field of study, but mathematics, computer and information sciences had the greatest enrolment surge between 2010 and 2019: a 115 percent increase (Figure 3).

Table 1: Percentage Growth in Postsecondary Enrolment from 2010 to 2019 by Field of Study, Institution and Level

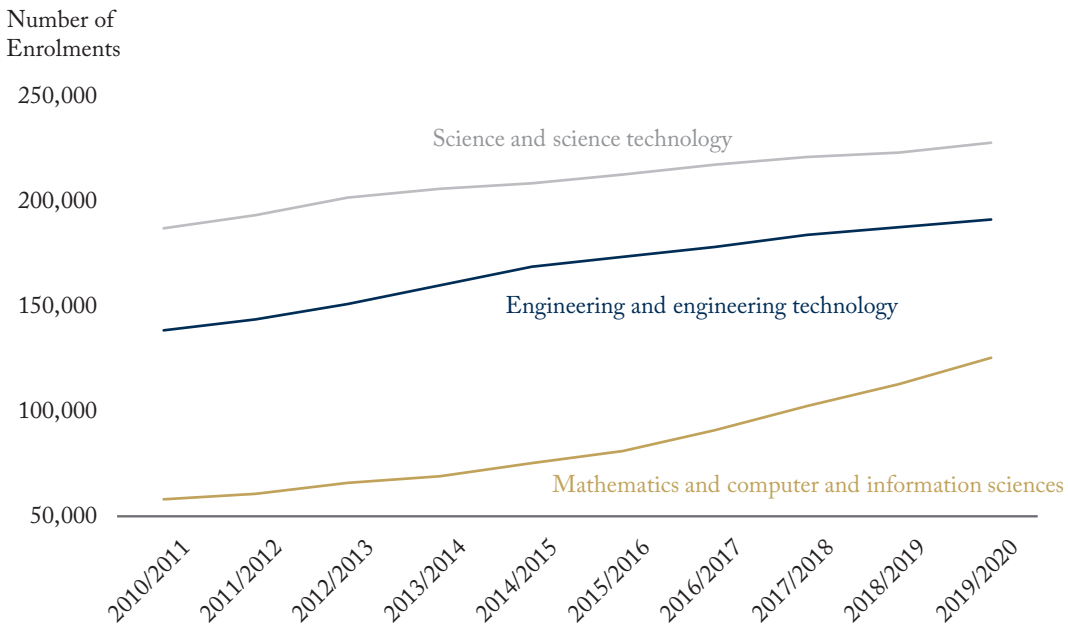
	All Programs	Non-STEM	STEM
	Percent		
All institution types	11.2	3.3	41.9
University	11.6	2.4	42.1
Bachelor's	11.1	0.5	44.5
Master's or higher	24.2	20.5	34.7
College	10.4	4.7	41.5

Note: Non-STEM are business, humanities, health, arts, social science, and education fields of study, categorized as BHASE programs.

Source: Statistics Canada, Postsecondary Student Information System, Table 37-10-0163-01.

Although, in accordance with enrolments, the number of graduates in STEM fields has increased strongly over time, four observations need to be made. First, not only was the total number of STEM graduates in 2019 far lower than the number of jobs added to the digital economy or to professional, scientific and technical services between 2018 and 2019, but also only a fraction of STEM graduates tend to work in STEM occupations, with women more likely than men to

Figure 3: Postsecondary Enrolments by STEM Category in Canada



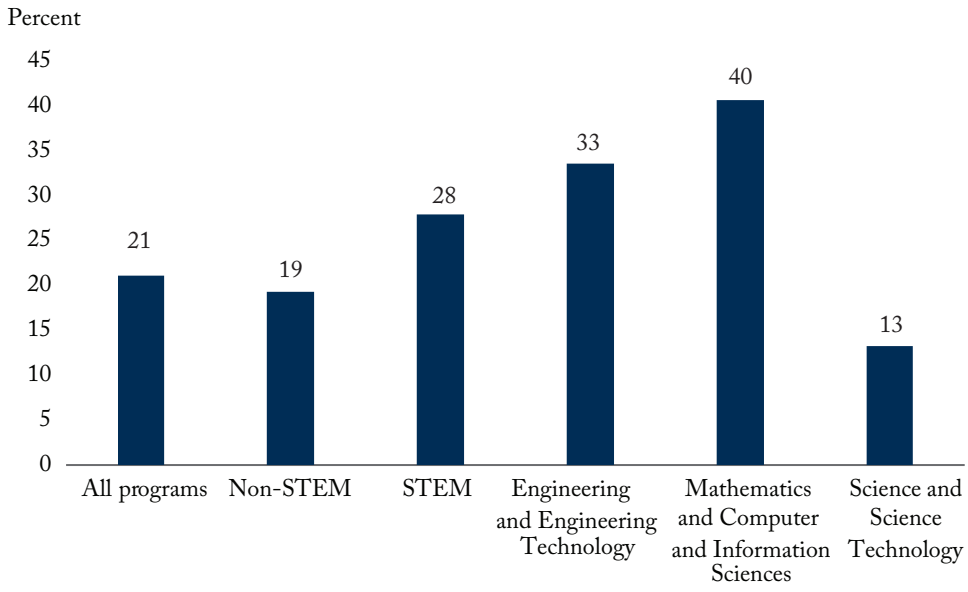
Source: Statistics Canada, Postsecondary Student Information System, Table 37-10-0163-01.

change their career pathway (Frank 2019).[6] Many ICT graduates, a major source of digital skills, also appear to change their career paths (ICTC 2015), affecting the potential skills supply.

Second, more than 21 percent of postsecondary graduates (123,177 graduates) in Canada in 2019 were international students (Figure 4). Moreover, the share of international graduates is higher in STEM fields (28 percent) – and within STEM, mathemathics and computer and information sciences has the highest share of international students (40 percent). This observation has an important implication, as some international students might choose to (or eventually have to) leave Canada after graduation, also affecting the supply of digital skills. In 2019, for example, only 11,565 (3.4 percent) of all admissions of permanent residents were related to those who were former international students, while there were 642,500 study permit holders in Canada (Canada 2022).

6 Reasons for changing career pathways among STEM graduates can include family obligations, lack of mentoring or guidance, lack of flexible work hours, and career progression obstacles following maternity or parental leaves of absence (Blickenstaff 2005; Dasgupta and Stout 2014; Engineers Canada and Geoscientists Canada 2016; Mavriplis et al. 2010; Preston 2004). Another factor could be related to the application of STEM skills in a range of occupations that could widen career options for STEM graduates (Council of Canadian Academies 2015).

Figure 4: Share of International Students among Graduates by STEM Category in 2019



Note: Non-STEM are business, humanities, health, arts, social science, and education fields of study, categorized as BHASE programs
Source: Statistics Canada, Postsecondary Student Information System, Table 37-10-0164-01.

The transition rate to permanent residency within the first ten years of international students who arrived in Canada after 2000 is three in ten (Choi, Crossman, and Hou, 2021). This highlights the importance of immigration policies with easier pathways for international students to secure permanent residency, particularly in STEM fields.

Third, some postsecondary students drop out of university or college or switch disciplines at some point during their studies. According to the Maritime Provinces Higher Education Commission (2018), the overall graduation rate from all Maritime universities was 59 percent after five years, increasing to 65 percent after six years for cohort year 2009; the six-year graduation rate in science and mathematics majors was 69.3 percent. At the national level, the six-year graduation rate in STEM for the 2013 cohort was 62.5 percent – 6.1 percentage points lower than the overall graduation rate in all fields of study (Statistics Canada 2022a),

Lastly, although postsecondary STEM graduates are a major source of digital skills, not all graduates might be prepared to work in the digital economy or have the skills employers are currently seeking. Wyonch (2020b) shows that graduates who participate in co-op programs and gain hands-on experience are more successful than STEM graduates without any co-op experience in the labour market – suggesting differences in work readiness among STEM graduates. In a recent survey of employers by the Business Council of Canada (2022), the share of employers who reported that recent graduates had the technical skills they need dropped from 96 percent in 2018 to 83.6 percent in 2022.

To increase the number of new graduates as a major source of digital skills supply, Canada needs not only to increase domestic enrolments in STEM fields, but also to ensure high persistence and graduation rates. Enhancing mathematic skills

during the elementary and secondary education years should help achieve these goals (Dooley et al. 2017; Wang 2013).

Canada's rankings in the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), remain well above average; however, scores of Canadian fifteen-year-old students in all three subjects of reading, mathematics and science have declined over time. The decline in mathematics – an important subject in the skilled high-tech economy – is particularly profound at the national level (a decline of 20 score points since 2003) and in all provinces other than Quebec. Although the 2018 Canadian average score of 512 in mathematics was above the OECD average score by 23 points, the score gap between high achievers and low achievers in Canada was 237 – close to the average 235-point difference in mathematics scores across all OECD countries. These PISA results require special attention from provincial governments, which are responsible for education, to reverse the trend in mathematics and reduce the gap between high and low achievers (O'Grady et al. 2019; Richards 2020a). An Indigenous indicator should also be included in all provincial samples to identify Indigenous students' skills gaps and publish their PISA results (Richards 2020b; Richards and Mahboubi 2018).

Finally, to address digital skills gaps in the labour market, it is also important to invest in the current workforce and encourage adult learning to gain workplace digital skills. According to a 2021 international survey of adults (ages 18 to 65) on their digital skills readiness by Salesforce, 30 percent of 973 Canadian participants reported that they were very prepared with workplace digital skills, but only 19 percent were very equipped with resources to learn digital skills and 14 percent were actively upskilling. Although self-reported preparedness is subjective and depends on a respondent's interpretation of digital skills, the shares of respondents who were not well equipped with the resources to up-skill or who were not participating in digital skills learning are concerning, given the growing importance of digital skills in the labour market.

The Gender Gap in STEM

The gender wage gap in Canada has diminished over time, largely owing to a substantial rise in higher educational attainment among women (Schirle 2020). But gender divides in fields of study associated with high-paying jobs – particularly in STEM fields – explain in part the remaining gender wage gap. In general, women are less likely to study or work in STEM fields. In September 2021, only 27.5 percent of ICT workers were women, while women's share of overall employment in the economy was 47.5 percent (Statistics Canada and ICTC 2021).

According to Statistics Canada (2021), about 56 percent of postsecondary enrolments in the 2019/20 academic year were women, but their share in STEM enrolment was just 38.5 percent – a share only slightly larger (by 2.4 percentage points) than in 2010/11 due to much faster growth of women's enrolment in STEM disciplines during the 2010s relative to men. Significant variations, however, exist across STEM categories. While women were considerably underrepresented in engineering and engineering technology (22 percent) and mathematics and computer and information sciences (28 percent), they formed the majority of science and science technology enrolment (58 percent). Selection into STEM categories contributes to gender earnings differences: according to the 2016 census, not only is average employment income for Canadians ages 25–64 with education in engineering and engineering technology higher than in other STEM categories, there are also substantial gender earnings gaps within each STEM category. Policy needs to address these gaps.

Gender gaps in STEM enrolments might be related to gender differences in math performance: there is a general link between STEM enrolment

in Canadian universities and higher PISA scores in mathematics at age fifteen (Trusty 2002; Trusty et al. 2000); moreover, girls moderately underperformed boys in mathematics in the PISA scores (O'Grady et al. 2019; Richards 2017). Ability in mathematics, however, is not the only factor influencing students' choice of a postsecondary program. Hango (2013) shows that only 23 percent of high-performing girls in PISA mathematics who went to university were in STEM fields, compared with 39 percent of low-performing boys. In an international study, Breda and Napp (2019) find that girls who were good at math in PISA scores had a larger comparative advantage in reading relative to boys with high ability in math. The difference between Canadian students' math and reading scores can explain about 35 percent of the gender gap in intentions to pursue studies and a career in maths.

Chan, Handler, and Frenette (2020) show that, among high-school graduates in British Columbia who enrolled in a bachelor's degree program, girls were 36.4 percent less likely than boys to choose a STEM field of study; only one-third of the difference can be explained by gender differences in academic performance in STEM-related high-school subjects. The authors argue that other contributing factors could be related to gender differences in STEM role models (teachers or parents), interest, confidence and societal norms.

These factors influence expectations of high-school students about their future and consequently their decisions. In the 2018 PISA, only 11 percent of girls self-reported that they expected to work as science and engineering professionals, ICT professionals or science-related technicians and associate professionals when they were thirty years old, compared with 28 percent of boys (CMEC 2021).

The digital shift now makes addressing the STEM gender gap more important than ever, as it could exacerbate existing gender inequalities in the labour market. Reducing the STEM gender gap requires policies that aim at closing achievement gaps in mathematics between girls and boys and better helping students make an informed choice of field of study and career. It is also important to assess and address potential structural factors that could be driving women and girls out of STEM disciplines. Examples of such factors include teaching methods, lack of mentorship, inhospitable learning or work environments in STEM-related areas and bias and discriminatory practices (Kricorian et al. 2020).

International Sources of Digital Skills Supply

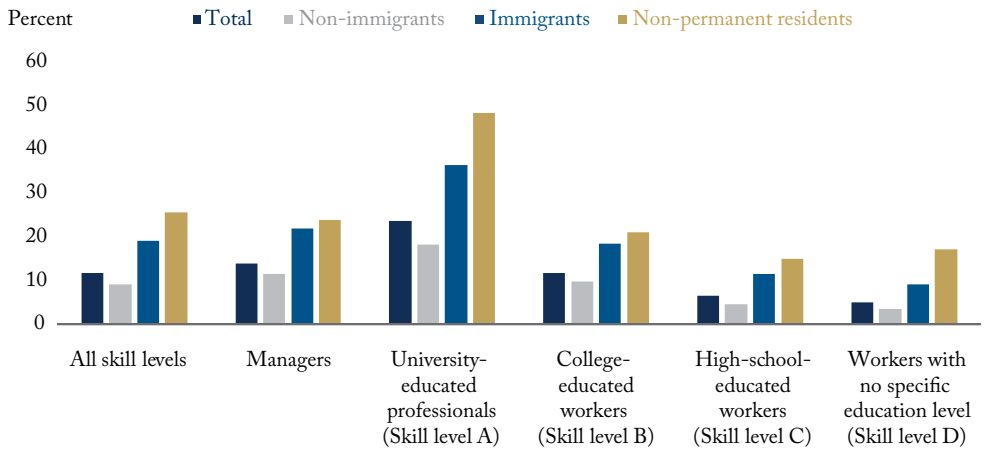
Although education and training in STEM fields to develop digital talent are a necessary part of the solution to digital skills shortages, immigration also plays an important role in addressing shortages, particularly in the short term and when the labour force growth is insufficient, limiting Canada's labour supply.

International sources of digital skills are immigrants and temporary foreign workers.[7] Because of its rapidly aging population, Canada is increasingly reliant on immigration for its labour force growth and to address skills shortages. Some sectors in particular rely heavily on immigration to meet their digital and STEM skills needs – for example, in 2016, 40 percent of ICT workers (more than 350,000 workers) were foreign born; only 4 percent of these were temporary foreign workers (Cameron and Faisal 2016).

Immigrants and temporary foreign workers are also more likely than the Canadian-born population

7 The government allows Canadian employers to hire foreign workers temporarily to meet their workforce needs when qualified Canadians are not available.

Figure 5: Share of Individuals Who Have Worked in STEM Occupations by Immigration Status and Skill Level, 2016 Census



Notes: The sample includes persons aged 25 to 64 who have worked at some point in time between January 2015 and May 2016. Immigrants include persons who are, or who have ever been, landed immigrants or permanent residents. Non-permanent residents include persons from another country who have a work or study permit or who are refugee claimants, as well as their family members sharing the same permit and living in Canada with them. Management reflects management occupations at the top of the organizational hierarchy; Skill level A reflects professional occupations and usually requires a university degree; skill level B is for occupations that usually require a college or apprenticeship training; skills level C includes occupations that usually require high school or job-specific training; and skill level D reflects occupations for which on-the-job training is given.

Source: Author's calculation using Statistics Canada, 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016272.

to be equipped with digital and STEM skills. This is partly due to the design of the immigration point-based system and the eligibility criteria of the Temporary Foreign Worker program, which prioritize high-skilled workers and require workers with these skills in in-demand occupations. According to the 2016 census, a higher proportion of immigrants and non-permanent residents in Canada were in STEM fields and occupations compared with non-immigrants, highlighting the role of immigration in addressing digital skills gaps (Figure 5).

The COVID-19 pandemic, however, has shown how quickly the inflow of immigrants can be interrupted: fewer than 185,000 newcomers arrived in 2020, representing a roughly 46 percent shortfall of the target of 340,000 (Canada 2022). In 2021, Canada achieved its target for that year and granted permanent residency to more skilled workers under

the Federal High Skilled category than planned.[8] But due to continuous border restrictions, many admissions were given to those who already resided in Canada with temporary status. The recent contribution of immigration to the new supply of digital talent thus has been limited.

Is There a Digital Brain Drain?

Canada is an attractive immigration destination, but there is also an outflow of Canadian residents (either Canadian or foreign born) pursuing better employment opportunities in other countries, particularly the United States. Although the number of people migrating south might not be the main concern, the characteristics of those who leave do matter. The reason is that, as I discuss later, quality of education matters. Regardless of immigration status, individuals who obtain their highest level of education in developed countries including Canada are typically more skilled.

According to the 2017 American Community Survey, which provides detailed data on social, economic and demographic characteristics of US residents, 72 percent of US immigrants ages 25–64 who lived in Canada a year earlier (2016) held a university degree. Among those university-educated immigrants from Canada, 56 percent were Canadian born. Regardless of place of birth, computer science was the top field of degree among university-educated, recent immigrants from Canada to the United States.

Canadian evidence based on LinkedIn profiles of 2015 and 2016 STEM graduates from the Universities of Toronto, British Columbia and Waterloo also show many of their graduates in ICT fields such as software engineering (66 percent), computer engineering (30 percent) and computer science (30 percent) leaving for the United States after graduation (Spicer, Olmstead, and Goodman 2018). However, it is important to note that many of these graduates are international students who may not intend to stay in Canada after graduation. This highlights the importance of better pathways to immigration for international students as these pathways may affect their decision. According to the profile of the University of Waterloo software engineering class of 2020, 84 percent of graduates had no plan to work and stay in Canada. One explanation could be related to work experience they might have gained in the United States through a co-op program: more than 91 percent of those graduates worked in the United States during at least one co-op term.

This evidence suggests that Canada faces a continuing digital brain drain to the United States, and needs to focus on policies that help retain Canadians with digital skills by creating opportunities comparable to those they might find elsewhere.

The increased ability and even desirability during the pandemic to work remotely seems to have allowed foreign employers to recruit and hire Canadian talent more easily without requiring them to move abroad (Lindzon 2021; Bergen 2021). To compete with foreign employers, Canadian employers need to offer a competitive package.

Addressing Digital Skills Gaps

Digital skills gaps can create operational challenges for employers, slow job growth and recovery and reduce competitiveness. They can also prevent innovative companies from growing, thus affecting

8 The Federal High Skilled category includes the Federal Skilled Worker Program, Federal Skilled Trades Program and Canadian Experience Class. The number of newcomers admitted under this category was close to 39 percent of total new immigrants in 2021 – about twelve percentage points above the planned level.

economic growth. There are two ways to address skills shortages: by developing and by attracting digital talent.

Developing Talent

A number of factors can influence individuals' decision to pursue a digital career or acquire digital skills, including ability, motivation, awareness of digital career opportunities and paths and access to high-quality education and learning opportunities. With these in mind, there is a role for policy makers, educational institutions and employers in supporting the building of skills domestically. This requires a holistic approach, including reforming the education system; expanding work integrated learning opportunities; and investing in adult education and training.

Reforming the Education System

Skills-biased technological changes are affecting the demand for high-skilled labour and digital skills, requiring some adjustments to Canada's education system. It is important to ensure that all Canadians, regardless of educational level, have strong STEM and basic digital and fundamental skills, since these skills are becoming more relevant and valuable in many types of jobs. Proficiency in these skills would also help individuals acquire in-demand digital skills more easily, highlighting the importance of elementary and secondary education in equipping students with the required skills. Since education is a provincial/territorial responsibility in Canada, all provinces and territories need to ensure that their education system aligns with ongoing digital demand and that their students graduate from high school with strong numeracy skills (Stokke 2015) and essential digital and computer science skills. Given the importance of mathematical skills, and due to the decline in its PISA mathematic results, Ontario has made some revisions to its elementary mathematics curriculum. Although Ontario still needs to monitor the effect of its revisions, other provinces should also review their mathematics curricula.

Other strategies to help meet the digital skills shortage in the long term include introducing the ICT field during primary and secondary school years to equip students with digital skills by establishing school curricula that include digital skills training. A review of initiatives by provincial governments shows that a large number either have a plan to add or have already added coding to the curriculum (Table 2).

It is pointless, however, to reform curricula to improve digital skills of students without adequate resources and teachers' preparedness to support implementation. In 2020, according to a national survey of elementary and middle school teachers in Canada, only 53 percent of teachers felt adequately prepared to teach STEM, and nearly all teachers agreed that there was room to improve their STEM skills. Barriers to the participation of teachers in STEM or digital skills professional development include lack of awareness about learning opportunities, limited opportunities, lack of time and cost (Munro 2020). Increasing awareness about and expanding initiatives such as CanCode – a federal program that supports digital skills training opportunities for student and teachers – are steps in the right direction.

Not all students, however, need to be a coder. Focusing on numeracy, logic, critical thinking, judgment and reasoning should provide the right "building blocks" to pick up more specific tech skills later on. This could be a better approach, since schools might not be able to keep up with the tools and technology given the rapid pace of change.

The digital divide could also be closed by strengthening digital infrastructure and by ensuring that all young Canadians have access to high-speed internet and digital services and develop digital literacy skills to enable them to participate and function in a digital world. Although the federal government recently announced support for low-income families and seniors to access affordable,

high-speed internet (Canada 2022b), there is a wide geographical urban-rural divide: only 53.4 percent of Canadians in rural communities have access to high-speed internet compared with 89.5 percent of all Canadians (CRTC 2022).

Governments also need to look at ways to increase STEM enrolment, ensure high graduation rates and close STEM gender gaps. Enhancing basic and digital skills during elementary and secondary education as well as better helping students make an informed choice of field of study and career – which highlights the important role of guidance counsellors in schools – could help achieve these goals.[9]

Furthermore, according to Technation (2020) – the Canadian technology companies' representative – in 2019 only fifteen public universities in Canada offered undergraduate and/or graduate AI and/or data science courses and programs. Provinces therefore should work with educational institutions to develop and expand course offerings and programs to fill the gap in this area.

In that regard, some businesses have taken steps and partnered with educational institutions and governments to provide STEM or specialized digital skills training options and programs. For example, Shopify partnered with the University of Waterloo to offer free, non-credit digital courses and with Carleton University and York University to launch an innovative computer science degree program (Dev Degree). In partnership with New Brunswick's Department of Education and CyberNB, Cisco Canada has supported a new education program with a cybersecurity curriculum.

Not all individuals, however, need to go to university to acquire digital skills and find employment in the ICT sector, even though it is considered to have a knowledge-intensive workforce. In 2017, 45 percent of workers in the ICT sector held no university degree (Canada 2021). There are alternative training options such as micro-credential programs to gain in-demand job skills and obtain non-university certifications and diplomas that have the potential to address some shortages in the short or medium term. For example, Google offers flexible online training, and grants professional certificates in various fields such as digital marketing, e-commerce, data

Table 2: Provincial Initiatives to Develop Digital Skills for K-12 Students

	Coding/ICT curriculum
Alberta	Coding curriculum for K-6
British Columbia	Coding curriculum for K-9, with optional classes for 10-12
Manitoba	Literacy with ICT across the curriculum for K-12
New Brunswick	Giving learners access to coding and digital literacy in schools; Mandatory Technology Education course for grades 6-8 and elective for other grades
Newfoundland and Labrador	N.A.
Nova Scotia	Coding curriculum for K-12; access to computer programming learning opportunities; Mandatory course for grade 10
Ontario	Included coding in the math curriculum K-8; Plan to include more hands-on learning, engineering design and coding in a new science curriculum for 1-8
Prince Edward Island	N.A.
Quebec	Implemented digital action plan for 2018-2023
Saskatchewan	N.A.

Source: Governments' websites and news articles.

9 In addition to educational policies, addressing the gender STEM divide requires policies and strategies that help improve inequalities within industry and occupation.

analytics and IT support. NPower Canada – an upskilling Canadian youth program – provides youth not in employment, education or training and underemployed youth with free, in-demand digital skills training and a pathway to work in the ICT sector.

Encouraging underrepresented groups such as women and Indigenous people[10] to take part in digital skills training or to continue their education in STEM fields would also help to address shortages. Although acquiring advanced digital skills would be more challenging for low-skilled individuals and those who lack formal STEM training, many should be able to gain basic digital skills by taking short-term training or even self-learning if they have access to the appropriate resources.

To address labour shortages, many tech companies in the United States, such as Google, Apple and IBM, have shifted their focus in hiring qualifications from education to skills, and have eliminated the postsecondary degree requirement for jobs. Canadian employers should also consider this approach and offer training tailored for their jobs, to the extent that it is possible to gain digital skills without formal higher education, in order to address the digital skills gaps the country is facing.

Expanding Work Integrated Learning Opportunities

Work integrated learning (WIL) is a type of experiential learning that enables postsecondary students to apply their academic knowledge to a job and gain workplace experience. This form of learning helps graduates to better adapt to the labour market after postsecondary education and to find a job that better matches their skills. Students gain the knowledge and skills they need in academic studies, and subsequently learn to apply those skills in a professional work environment.

Wyonch (2020b) shows that participating in school/work co-op programs is linked to higher incomes and a higher likelihood of success in the labour market after graduation, and that women, visible minorities and immigrants and those in STEM fields get more benefits than others.

In addition to investments in WIL opportunities for postsecondary students, the federal government has introduced initiatives such as the Natural Sciences and Engineering Research Council of Canada's Young Innovators grant and PromoScience program to support hands-on learning experiences for elementary and high-school students.

Canadian policymakers and educational institutions should continue to expand co-op programs and WIL opportunities to make them accessible to more students. Boosting co-op programs, particularly in STEM subjects, would increase the significant benefits of participation in co-ops by easing the transition into the labour market.

Investing in Adult Education and Training

An important policy issue for any government should be improving workforce skills and reducing mismatches due to skills shortages (Mahboubi 2017, 2019). A traditional way to enhance skills is through formal education directed mainly at young people and provided on a full-time basis. However, with changes in the labour market and shifts in demand for digital skills, providing opportunities for all to upgrade their skills and equipping them

10 According to the 2016 census, 4.3 percent of the Canadian working-age population is Indigenous, but the share of Indigenous people in STEM jobs is 1.7 percent. This is due to their lower employment rate as well as gaps in skills and educational outcomes compared with the non-Indigenous population (Mahboubi and Busby 2019; Richards 2020a; Richards and Mahboubi 2018).

with workplace-essential digital skills are becoming increasingly important.

The federal government has already taken steps to support digital skills development, particularly among young Canadians, through initiatives such as Digital Skills for Youth and the Canada Digital Adoption Program. Other general training programs could also be used to develop Canadians' digital skills. In their review of these skills development strategies, Mahboubi and Mokaya (2021) argue that Canada lacks a comprehensive approach toward lifelong learning, and needs to do more to improve eligibility criteria, address barriers to participation and create a strong partnership with businesses and educational institutions. Creating stronger government-business partnerships (especially with SMEs), while fostering networks to promote workplace training, is paramount (Kronfli 2020). Businesses should also invest in their employees and play their important role in digital skills development.

In general, adaptability, flexibility and a commitment to adult education and training will be crucial, especially as industries and companies reposition themselves in a highly data-driven, digital world. Governments and businesses should improve and invest in digital and data skills development programs and consider strategies that encourage participation by adult learners. This will require identifying and addressing barriers to participation, incentivizing participation and raising awareness about available training opportunities.

Attracting Talent

Immigration is a major source of labour force growth and digital skills. Canada attracts global skilled talent, permanently or temporarily, through various federal and provincial programs. Immigration programs include the Federal Skilled Worker Program (FSWP), the Canadian Experience Class (CEC) and the Provincial Nominee Program (PNP), while temporary pathways fall under the Temporary Foreign Worker Program (TFWP) and the International Mobility Program. Immigration programs with a high level of a two-step selection process that prioritizes potential applicants with Canadian education and experience – for example, international students in the PNP and temporary foreign workers in the CEC – have been particularly effective for immigrants' success (Hou, Crossman, and Picot 2020; Skuterud and Chen 2018) and have helped retain talent in Canada.

As mentioned earlier, however, only 3.4 percent of newcomers in 2019 previously held a study permit – a share that increased to 5.6 percent in the second quarter of 2021 due to a shift toward the admission of more temporary residents to meet immigration target levels in light of the pandemic. New Brunswick has created a new category for Express Entry of skilled immigrants in occupations in demand without requiring a job offer. Since the requirement for a job offer has been a barrier to admission of former international students, this new provincial program will likely ease their path to permanent residency.

Giving permanent resident status to temporary residents in Canada is mostly effective for the retention of talent, but it has no effect on the supply of talent if these workers are already employed. The federal government thus needs to make sure of an adequate supply of workers with new digital skills through immigration policies and the Temporary Foreign Worker Program. In that regard, for example, the federal government has implemented the Global Skills Strategy since 2017 as part of the TFWP to provide employers with streamlined, predictable and timely access to global talent in STEM and ICT, through faster processing of Labour Market Impact Assessments, with a service standard of ten business days.

Ontario, Alberta and British Columbia have recently introduced pilot immigration programs specifically for tech professionals to meet their provincial digital skills needs. However, Canada has a backlog of temporary and permanent residence applications that reached 2.4 million in May

2022 (El-Assal 2022) and fairly long processing times – for example, 26 months for processing FSWP applications as of July 2022 (Canada 2022a).[11] These backlogs and long processing times need to be addressed, as they can pose a risk to Canada's ability to attract and retain top talent. The government's recent announcement of its plan to create a fast-track immigration program for temporary residents is a step in the right direction. However, governments at all levels need to ensure that employers contribute to investment in skills training for Canada to address skills shortages domestically in the long term.

Governments also need to make sure that immigrants' skills are put fully to use through a better selection policy and post-immigration supports. Internationally educated newcomers often face challenges finding employment that matches their qualifications. Picot and Hou (2019) show that employed STEM-educated immigrants with a bachelor's degree had considerably lower skills-utilization rates and earnings outcomes relative to their non-immigrant counterparts. These gaps declined, however, among those with a doctoral degree, since they were more likely to obtain their highest level of education in Canada or countries such as the United States, the United Kingdom and France. One explanation is that immigrants who obtained their highest level of education in these countries have better language skills than other immigrants, and language ability appears to be a major barrier to immigrants transferring their skills into productive employment (Mahboubi 2017).

In a US-Canada comparison, Picot and Hou (2020) show that, although more than 50 percent of STEM-educated immigrants held non-STEM jobs in both countries, only about 20 percent of these immigrant workers were employed in non-STEM jobs that required a university education in Canada, compared with 48 percent in the United States. After accounting for differences in socioeconomic characteristics, including where immigrants obtained their highest level of education, the authors find a large earnings gap between STEM-educated immigrants and native-born workers only in Canada, arguing this can be explained by differences in the country of education and the quality of STEM-educated immigrants: STEM-educated immigrants from developed countries have better labour outcomes than other STEM-educated immigrants; among STEM-educated immigrants ages 25 to 64 who entered the United States and Canada as adults, 32 percent and 22 percent, respectively, received their highest degree in the host country (Picot and Hou 2020).

Lastly, although immigration remains an important tool in the short term for supporting the digital economy, addressing skills shortages through immigration might not be sustainable in the long term, given global competition to attract and retain top talent. Canada is among the top destination countries for immigration and ranks high in terms of immigrant-friendly policies, but its major competitors – the United States, United Kingdom, New Zealand and Australia – are similarly facing talent shortages and constantly trying to improve their immigration policies and attractiveness. For example, the United Kingdom introduced a points-based immigration system in 2020 to select top global talent, and intends to offer a work visa without a job offer to any graduates who are fluent in English from the top fifty universities in the world. To compete for this talent, therefore, Canada should make itself more attractive to skilled workers, not only in terms of attracting immigration, but also in retaining domestic talent and preventing brain drain. This means that, in addition to immigration policy, Canada needs

11 Prior to COVID-19, the processing time was approximately six months.

to evaluate labour market policies. For example, although language is a critical factor for immigrants' integration, the recent attempt to strengthen Quebec's language laws and expand French-language requirements to smaller businesses under Bill 96 could limit employers' ability to attract and retain top talent in Quebec. Canadian employers could also play an important role in attracting and retaining talent by offering competitive compensation and benefits packages.

Conclusion

To respond to growing digital skills needs and shortages, Canada needs to increase its supply of people with digital skills and to invest in the reskilling and upskilling of its workforce. The sources of digital skills are new graduates, labour market transitioners, the out-of-workforce population and newcomers. Therefore, Canada should focus on developing talent by enhancing education quality, increasing STEM enrolments and graduations and supporting WIL opportunities in STEM fields.

In short, Canada needs to address inequalities and gaps in STEM fields and occupations, offer pathways into these sectors for youth and other groups who face barriers to employment and attract top digital talent through fast-track immigration programs and the Temporary Foreign Worker Program. It also needs to pay attention to the retention of talent, otherwise strategies to help increase the number of graduates and immigrants will weaken. Expanding the pool of digital talent will also require higher wages to attract more workers, on-the-job training opportunities to address skills gaps, a shift in educational focus from degrees to skills acquisition and recognition and support of non-formal training options.

REFERENCES

Beauplat, J. 2021. "Game over? Canadian video game techs heading to jobs in other sectors." *Montreal Gazette*, August 6. https://montrealgazette.com/news/local-news/game-over-canadian-video-game-techs-heading-to-jobs-in-other-sectors.

Bellatin, Alejandra, and Gabriela Galassi. 2021. "Canadian job postings in digital sectors during COVID-19."Bank of Canada Staff Analytical Note. August. https://www.bankofcanada.ca/wp-content/uploads/2021/08/san2021-18.pdf.

Bergen, B. 2021. "Canada's New Brain Drain Problem." Council of Canadian Innovators, June 28. https://canadianinnovators.medium.com/canadas-new-brain-drain-problem-edc58bfedbc7.

Blickenstaff, J.C. 2005. "Women and Science Careers: Leaky Pipeline or Gender Filter?" *Gender and Education* 17 (4): 369–86. https://doi.org/10.1080/09540250500145072.

Bughin, Jacques, Eric Hazan, Susan Lund, Peter Dahlström, Anna Wiesinger, and Amresh Subramaniam. 2018. "Skill Shift: Automation and the Future of the Workforce." Discussion paper. McKinsey & Company.

Breda, Thomas, and Clotilde Knapp. 2019. "Girls' Comparative Advantage in Reading Can Largely Account for the Gender Gap in Math-Intensive Fields." IZA Discussion Paper No. 12503.

Business Council of Canada. 2022. "Empowering People for Recovery and Growth: 2022 Skills Survey Report." Business + Higher Education Roundtable. March.

Cameron, A., and S. Faisal. 2016. "Digital Economy Talent Supply: Immigration Stream." Ottawa: Information and Communications Technology Council.

Canada. 2021. "Canadian ICT Sector Profile 2020." Ottawa: Innovation, Science and Economic Development Canada. https://ised-isde.canada.ca/site/digital-technologies-ict/en/canadian-ict-sector-profile.

Canada. 2022. Immigration, Refugees and Citizenship Canada website Available at: https://www.canada.ca/en/immigration-refugees-citizenship/corporate/reports-statistics/statistics-open-data.html

———. 2022a. "Check Processing Times." https://www.canada.ca/en/immigration-refugees-citizenship/services/application/check-processing-times.html.

———. 2022b. "Government of Canada announces affordable high-speed Internet to help connect low-income families and seniors." News release, April 4. https://www.canada.ca/en/innovation-science-economic-development/news/2022/04/government-of-canada-announces-affordable-high-speed-internet-to-help-connect-low-income-families-and-seniors.html.

Chan, Ping, Winnie Ching, Tomasz Handler, and Marc Frenette. 2020. "Gender Differences in STEM Enrolment and Graduation: What Are the Roles of Academic Performance and Preparation?" Cat. no. 36-28-0001. Ottawa: Statistics Canada.

Choi, Youjin, Eden Crossman, and Feng Hou. 2021. "International Students as a Source of Labour Supply: Transition to Permanent Residency." *Economic and Social Reports* 1 (6). Statistics Canada, cat. no. 36-28-0001.

Council of Canadian Academies. 2015. *Some Assembly Required: STEM Skills in Canada's Economic Productivity*. Ottawa: Council of Canadian Academies.

CMEC (Council of Ministers of Education Canada). 2021. "Trends in STEM and BHASE Graduates from Public Postsecondary Institutions across Canadian Provinces and Territories 2010 to 2018." Council of Ministers of Education Canada.

CRTC (Canadian Radio-television and Telecommunications Commission). 2022. "Broadband Fund: Closing the Digital Divide in Canada." https://crtc.gc.ca/eng/internet/internet.htm.

Dasgupta, N., and J.G. Stout. 2014. "Girls and Women in Science, Technology, Engineering, and Mathematics: Stemming the Tide and Broadening Participation in STEM Careers." *Policy Insights from the Behavioral and Brain Sciences* 1 (1): 21–9. https://doi.org/10.1177%2F2372732214549471.

Deschamps, T. 2022. "Tech group proposes visa for skilled workers to enter country without a job offer." *Global News*, March 31. https://globalnews.ca/news/8724724/tech-group-wants-new-visa-tech-workers/.

———. 2022b. "Canadian tech talent still in demand, despite layoffs and recession predictions." *CTV News*, July 10. https://www.ctvnews.ca/sci-tech/canadian-tech-talent-still-in-demand-despite-layoffs-and-recession-predictions-1.5981652.

Dooley, Martin, Abigail Payne, Mitchell Steffler, and Jessica Wagner, 2017. "Understanding the STEM Path through High School and into University Programs." *Canadian Public Policy* 43 (1): 1–16. https://doi.org/10.3138/cpp.2016-007.

El-Assal, K. 2022. "Canada's immigration backlog jumps to 2.4 million persons." *CIC News*, June 16. https://www.cicnews.com/2022/06/canadas-immigration-backlog-jumps-to-2-4-million-persons-0626324.html#gs.5izzqv.

Engineers Canada and Geoscientists Canada. 2016. "Managing Transitions: Before, During and After Leave." Available at: https://engineerscanada.ca/sites/default/files/Managing-Transitionsen.pdf (accessed June 25, 2018).

ESAC (Entertainment Software Association of Canada). 2021. "The Canadian Video Game Industry 2021." https://theesa.ca/wp-content/uploads/2021/11/esac-2021-final-report.pdf.

Feijao, Carolina, Isabel Flanagan, Christian van Stolk, and Salil Gunashekar. 2021. "The Global Digital Skills Gap: Current Trends and Future Directions." RAND Europe. December.

Frank, Kristyn. 2019. "A Gender Analysis of the Occupational Pathways of STEM Graduates in Canada." Cat. no. 11F0019M – No. 11. Ottawa: Statistics Canada.

Hango, D.W. 2013. Gender differences in science, technology, engineering, mathematics and computer science (STEM) programs at university. Insights on Canadian Society. Ottawa. Canada. Statistics Canada.

Hou Feng, Eden Crossman, and Garnett Picot. 2020. "Two-step Immigration Selection: Why Did Immigrant Labour Market Outcomes Vary by Admission Programs?" Cat. no. 11-626-X – 2020015 – No. 117. Ottawa: Statistics Canada.

ICTC (Information and Communications Technology Council). 2015. Digital Economy Supply Canada's Post-Secondary Education Stream. Ottawa: Information and Communications Technology Council. https://www.ictc-ctic.ca/wp-content/uploads/2015/07/ICT-Talent-Supply-English-UPDATED.pdf

———. 2022. *Digital Economy Annual Review 2019*. Ottawa: Information and Communications Technology Council.

———. 2021. Digital Economy Labour Market: Monthly Snapshot. September. https://www.ictc-ctic.ca/wp-content/uploads/2021/10/September-2021-MONTHLY-SNAPSHOT.pdf

Ivus, M., and A. Kotak. 2021. "Onwards and Upwards – Digital Talent Outlook 2025." Ottawa: Information and Communications Technology Council.

Kricorian, Katherine, Michelle Seu, Daniel Lopez, Elsie Ureta, and Ozlem Equils. 2020. "Factors Influencing Participation of Underrepresented Students in STEM Fields: Matched Mentors and Mindsets." *International Journal of STEM Education* 7 (16). https://doi.org/10.1186/s40594-020-00219-2.

Kronfli, C. (2021). Small business, big impact: How SMEs are pivoting during COVID-19. COVID-19 Policy Brief – 03. Ontario Chamber of Commerce. https://occ.ca/wp-content/uploads/SME-Report-June22.pdf

Lindzon, J. 2021. "Look for a reverse 'brain drain' as more remote workers choose to stay home or return from the U.S." *Globe and Mail*, August 27. https://www.theglobeandmail.com/business/careers/article-look-for-a-reverse-brain-drain-as-more-remote-workers-choose-to-stay/.

Mahboubi, Parisa. 2017. "Talkin' 'Bout My Generation: More Educated, but Less Skilled Canadians." E-Brief. Toronto: C.D. Howe Institute.

———. 2019. *Bad Fits: The Causes, Extent and Costs of Job Skills Mismatch in Canada*. Commentary 552. Toronto: C.D. Howe Institute.

Mahboubi, Parisa, and Colin Busby. 2019. "Closing the Divide: Progress and Challenges in Adult Skills Development among Indigenous Peoples." E-Brief. Toronto: C.D. Howe Institute.

Mahboubi, Parisa, and Momanyi Mokaya. 2021. *The Skills Imperative: Workforce Development Strategies Post-COVID*. Commentary 609. Toronto: C.D. Howe Institute.

Maritime Provinces Higher Education Commission. 2018. "Student Progression in the Maritime University System: Persistence and Graduation."

Massé, I. 2021. "Workers wanted for video game and visual effects development." *Toronto Star*, August 9. https://www.thestar.com/news/canada/2021/08/09/workers-wanted-for-video-game-and-visual-effects-development.html.

Mavriplis, C., R. Heller, C. Beil, K. Dam, N. Yassinskaya, M. Shaw, and C. Sorensen. 2010. "Mind the Gap: Women in STEM Career Breaks." *Journal of Technology Management and Innovation* 5 (1): 140–51. https://doi.org/10.4067/S0718-27242010000100011.

Munro, Danile. 2020. "Canadian Teachers' Readiness for STEM Education: Results from Actua's National Survey of Teachers." Actua. September. https://actua.ca/wp-content/uploads/2022/03/For-Publication_Actua-National-Teacher-Survey-Report_2020-2-1.pdf.

O'Grady, K., M. Deussing, T. Scerbina, Y. Tao, K. Fung, V. Elez, and J. Monk. 2019. "Measuring up: Canadian Results of the OECD PISA 2018 Study." Council of Ministers of Education Canada.

Picot, G., and F. Hou. 2019. The Skill Utilization and Earnings of STEM-educated immigrants in Canada: Differences by Degree Level and Field of Study. Analytical Studies Branch Research Paper Series, no. 435. Statistics Canada Catalogue no. 11F0019M. Ottawa: Statistics Canada.

———. 2020. A Canada–U.S. Comparison of the Economic Outcomes of STEM Immigrants. Analytical Studies Branch Research Paper Series, no. 435. Statistics Canada Catalogue no. 11F0019M No. 453. Ottawa: Statistics Canada.

Preston, A.E. 2004. *Leaving Science: Occupational Exit from Scientific Careers*. New York: Russell Sage Foundation.

Randstad. 2015. "Confronting Canada's Technical Talent Shortage: Expanding the Pool of STEM-Skilled Individuals to Foster Innovation and Business Success." https://content.randstad.ca/hubfs/STEM_2015/Randstad_STEM_WP_EN.pdf.

Richards, John. 2017. *Red Flags for Educators: Lessons for Canada in the PISA Results*. Commentary 488. Toronto: C.D. Howe Institute. August.

———. 2018. *Pursuing Reconciliation: The Case for an Off-Reserve Urban Agenda*. Commentary 526. Toronto: C.D. Howe Institute. November

———. 2020. "No Easy Answers: Insights into Community Well-being among First Nations." E-Brief. Toronto: C.D. Howe Institute. May.

Richards, John, and Parisa Mahboubi. 2018. "Measuring Student Outcomes: The Case for Identifying Indigenous Students in Canada's PISA Sample." E-Brief. Toronto: C.D. Howe Institute

Saba, Tania, and Simon Blanchette. 2020. "Small and Medium-Sized Employers (SMEs): Skill Gaps and Future Skills." Ottawa: Public Policy Forum, Diversity Institute at Ryerson University and Future Skills Centre. https://www.ryerson.ca/diversity/reports/SmallAndMediumSizeEmployers-EN.pdf.

Schirle, Tammy. 2020. *A Work in Progress: Measuring Wage Gaps for Women and Minorities in the Canadian Labour Market*. Commentary 561. Toronto: C.D. Howe Institute. January.

Shortt, Denise, Brian Robson, and Magdalena Sabat. 2020. "Bridging the Digital Skills Gap: Alternative Pathways." Ottawa: Public Policy Forum, Diversity Institute at Ryerson University and Future Skills Centre. https://technationcanada.ca/wp-content/uploads/2020/10/DigitalSkills-AlternativePathways-PPF-JAN2020-EN-1.pdf.

Skuterud, Mikal and Zong Jia Chen 2018. *Comparing Outcomes: The Relative Job-Market Performance of Former International Students*. Commentary 518. Toronto: C.D. Howe Institute. August.

Spicer, Zachary, Nathan Olmstead, and Nicole Goodman. 2018. "Reversing the Brain Drain: Where Is Canadian STEM Talent Going?" Toronto: University of Toronto, Munk School of Global Affairs.

Statistics Canada. 2021. "Postsecondary Enrolments, by International Standard Classification of Education, Institution Type, Classification of Instructional Programs, STEM and BHASE Groupings, Status of Student in Canada, Age Group and Gender." Table 37-10-0163-01. Ottawa.

———. 2022a. "Graduation of Career, Technical or Professional Training Certificate Students, within the STEM/BHASE (Non-STEM) Grouping and Province or Territory of First Enrolment, by Student Characteristics." Table 37-10-0145-01. Ottawa.

———. 2022b. "Job Vacancies, Proportion of Job Vacancies and Average Offered Hourly Wage by Selected Characteristics, Quarterly, Unadjusted for Seasonality." Table 14-10-0328-01. Ottawa.

Statistics Canada. Table 14-10-0287-01 Labour force characteristics, monthly, seasonally adjusted and trend-cycle, last 5 months DOI: https://doi.org/10.25318/1410028701-eng

Stokke, A. 2015. *What to Do about Canada's Declining Math Scores?* Commentary 427. Toronto: C.D. Howe Institute. May.

Technation. 2020. "Skilling Canadians for Leadership in the AI Economy." https://munkschool.utoronto.ca/ipl/files/2020/09/Ticoll_Skilling-Canadians-for-Leadership-in-the-AI-Economy-2020.pdf.

Trusty, J. 2002. Effects of high school course-taking and other variables on choice of science. *Journal of Counseling and Development*, 80(4): 464–7

Trusty, J., C. R. Robinson, M. Plata, and K.-M. Ng. 2000. Effects of gender, socioeconomic status, and early academic performance on postsecondary educational choice. Journal of Counseling & Development, 78(4), 463–472. https://doi.org/10.1002/j.1556-6676.2000.tb01930.x

Wang, Xueli. 2013. "Why Students Choose STEM Majors: Motivation, High School Learning, and Postsecondary Context of Support." American Educational Research Journal 50 (5): 1081–121. http://www.jstor.org/stable/23526124.

World Economic Forum. 2020. *The Future of Jobs Report 2020*. Geneva: World Economic Forum.

Wyonch, Rosalie. 2020a. *The Next Wave: Automation and Canada's Labour Market*. Commentary 585. Toronto: C.D. Howe Institute. November.

———. 2020b. *Work-Ready Graduates: The Role of Co-op Programs in Labour Market Success*. Commentary 562. Toronto: C.D. Howe Institute. January.

NOTES:

Recent C.D. Howe Institute Publications

July 2022	Lester, John. "Tax Support for R&D and Intellectual Property: Time for Some Bold Moves." C.D. Howe Institute E-Brief.
July 2022	Mahboubi, Parisa, and Amira Higazy. *Lives Put on Hold: The Impact of the COVID-19 Pandemic on Canada's Youth.* C.D. Howe Institute Commentary 624.
July 2022	Ambler, Steve, and Jeremy Kronick. *Money Talks: The Old, New Tool for Predicting Inflation.* C.D. Howe Institute Commentary 623.
June 2022	Hodgson, Glen. "Climate Risk and Canadian Banks: Is More Capital Required?" C.D. Howe Institute E-Brief.
May 2022	Nikolakakis, Angelo. "High Stakes Ahead: Canada and the Global Minimum Tax for Multinationals." C.D. Howe Institute E-Brief.
May 2022	Baldwin, Bob. "The Evolving Wealth of Canadians: Who Is Better Fixed for Retirement? Who is Not?" C.D. Howe Institute E-Brief.
May 2022	Grootendorst, Paul, Javad Moradpour, Michael Schunk, and Robert Van Exan. *Home Remedies: How Should Canada Acquire Vaccines for the Next Pandemic?* C.D. Howe Institute Commentary 622.
April 2022	Blomqvist, Åke. *Going Dutch: Choice, Competition and Equity in Healthcare.* C.D. Howe Institute Commentary 621.
April 2022	Jackson, Catherine, with Abhishek Kumar, and Ramisha Asghar. *Put to the Test: Ranking Canada's Universities on Their Climate Change and Endowment Activities*. C.D. Howe Institute Commentary 620.
April 2022	Ciuriak, Dan. "The Economic Consequences of Russia's War on Ukraine." C.D. Howe Institute Verbatim.
April 2022	Lester, John. "An Intellectual Property Box for Canada: Why and How." C.D. Howe Institute E-Brief.

Support the Institute

For more information on supporting the C.D. Howe Institute's vital policy work, through charitable giving or membership, please go to www.cdhowe.org or call 416-865-1904. Learn more about the Institute's activities and how to make a donation at the same time. You will receive a tax receipt for your gift.

A Reputation for Independent, Nonpartisan Research

The C.D. Howe Institute's reputation for independent, reasoned and relevant public policy research of the highest quality is its chief asset, and underpins the credibility and effectiveness of its work. Independence and nonpartisanship are core Institute values that inform its approach to research, guide the actions of its professional staff and limit the types of financial contributions that the Institute will accept.

For our full Independence and Nonpartisanship Policy go to www.cdhowe.org.

C.D. HOWE
INSTITUTE

67 Yonge Street, Suite 300,
Toronto, Ontario
M5E 1J8

Canadian Publication Mail Sales
Product Agreement #40008848