SKILLING CANADIANS FOR LEADERSHIP IN THE AI ECONOMY

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TECHNATION^{CA}

About TECHNATION

About the Author

TECHNATION is the industry-government nexus for technology prosperity in Canada. As a member-driven, not-for-profit, TECHNATION unites Canada's technology sector, governments and communities to enable technology prosperity from coast to coast to coast. TECHNATION champions technology prosperity from coast to coast to coast by providing advocacy, professional development and networking opportunities across industry and governments at all levels; connecting Canadian scale-ups with global tech leaders; engaging the global supply chain; and filling the technology talent pipeline. TECHNATION has been the authoritative national voice of the $184 billion Information and Communication Technology (ICT) industry in Canada for over 60 years. *TECHNATION was formerly the Information Technology Association of Canada (ITAC).*

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Special thanks

Several individuals in each of the following organizations made important contributions to the development and validation of the analysis and recommendations of this report. The insights and perspectives they provided were essential to the outcomes of this work. We thank them for sharing their time, knowledge, research and experiences with us. Having said this, TECHNATION takes sole responsibility for the contents of this report.

Cisco Sytems	IDC Canada
Colleges & Institutes Canada	Microsoft Canada
Dawson College	Rio Tinto
Deloitte	Scale.ai Supercluster
Dessa	University of Alberta
IBM Canada	University of Toronto

Canada

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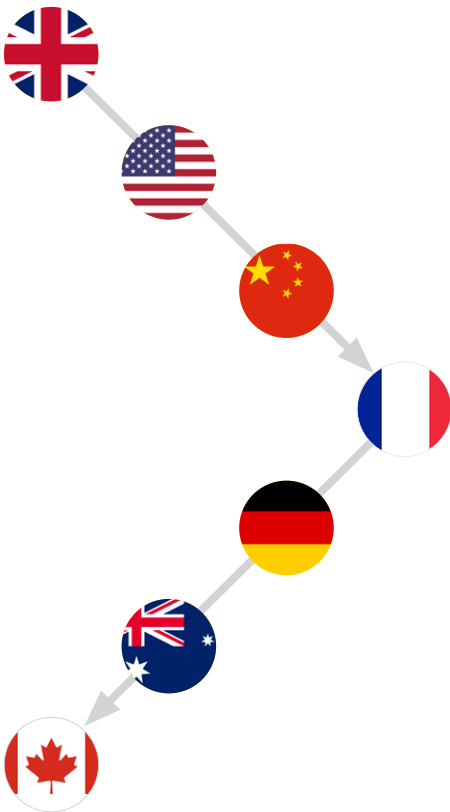
Canadian executives rank

last

in recognition of the
strategic importance of AI

The world's largest countries and corporations—in all sectors, from retail to health care, finance to manufacturing—are investing massively in artificial intelligence (AI) and related technologies. Those who make smart, strategic investments will be better poised for success in facing the challenges of a post-COVID world.

Currently, Canada does not fall into this category. This country has crucial competitive advantages, including quality education systems and a skilled and diverse workforce. However, some surveys suggest that Canada lags the global leaders in AI adoption and AI skills availability.

Our research revealed that Canada's AI-related job postings increased from 2,218 in 2015 to 6,840 in 2018, a compound annual growth rate of **46 per cent**. However:

- Canadian executives rank *last* in recognition of the strategic importance of AI for business success among seven leading countries.[1]

- Demand for skillsets essential to deployment of AI in business organizations is insufficient.

- 72 per cent of Canadian executives face moderate to extreme AI skills gaps.

- AI-related courses in universities and colleges have long wait lists and crowded classrooms; not enough AI educators are available.

The data contained in this Report provides evidence of dramatic growth in demand for AI talent over the 2015-2018 period. This should be interpreted as a snapshot of a point in time. Further research is needed to validate the trends identified herein.

This Report also unveils the *TECHNATION AI Jobs and Skills Framework*, a starting point for workforce planning, skills development and labour market analysis.

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1   Countries surveyed were Australia (100 respondents), Canada (300), China (100), Germany (100), France (100), United Kingdom (100) and United States (1100). Deloitte, <u>Future in the balance? How countries are pursuing an AI advantage</u> published May 1, 2019.

It also provides recommendations for government leaders on how to build national AI awareness and literacy, and ways government and industry can collaborate to accelerate AI skills and capability development, particularly in lagging sectors. Recommendations for the education sector on developing AI initiatives at all levels are also presented.

Finally, the Report offers a roadmap to improving Canada's AI capabilities and positioning the country's workers, students, businesses and public sector for success in the global AI economy.

This report is based on TECHNATION analysis of industry trends, consultations with leading AI sector and education practitioners (see Acknowledgements on page 3), and an employer demand data snapshot based on Canadian job postings provided by Burning Glass, a research firm that specializes in labour market analytics. The snapshot compares the years 2018 and 2015. Unless indicated otherwise, data cited herein derives from this commissioned research. For details on the methodology and its limitations, see Appendix D.

Introduction:
The AI skills stakes for Canada

"You need to be literate in AI to function in the modern world. It's become an essential skill, like numeracy."

Ray Bourgeois,
Dean of Academic Initiatives,
Dawson College, Montreal

► Canada lags global leaders in AI adoption.

► Most Canadian executives do not understand the implications of AI for their business.

► Globally, executives report increased revenue and lower costs from AI adoption. But in Canada, fewer than a quarter of those surveyed embed AI in any of their products and services.

► 72% of Canadian businesses report AI skills gaps.

► Educational institutions cannot keep up with demand for AI skills training.

AI is changing how Canadians live and work. We are immersed in an AI-based world, punctuated by digital and social media, retail interactions, voice assistants and smart devices. AI will also change almost everything about how organizations make decisions, create, function, compete and engage with customers.

Canada's AI sector is rooted in decades of innovation. Breakthroughs in processing power, data management and algorithm design proved the practical commercial value of AI: machine learning and deep learning in particular. In its 2017 budget, the federal government announced the $125-million Pan-Canadian AI Strategy, the world's first national AI strategy. This program involves public-private-academic sector investments in research centres in Montreal, Toronto, Edmonton and elsewhere. The strategy inspired a fertile ecosystem of AI start-ups, scale-ups and global firms. Canada is a recognized innovating force in the design and construction of technologies and infrastructure for pure and hybrid AI applications.

That's the good news.

The not so good news is this: AI skills and adoption across the economy, where more than 95 per cent of Canadian GDP is created and nearly all Canadians work, is uneven at best—and startlingly lacking at worst.

Across the mainstream economy, Canada lags peer countries in AI adoption and capability development.

72%

of Canadian AI-engaged executives face **moderate to extreme AI skill gaps**
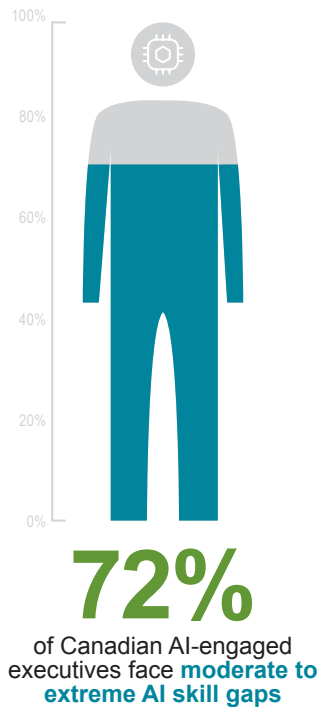
Across the mainstream economy, Canada lags peer countries in AI adoption and capability development. Few Canadian companies, educators, policymakers and career choosers understand AI's capabilities and limitations. A 2018 Deloitte study of AI-engaged executives in seven leading countries found:[2]

- Canada is **last** in employer recognition of the strategic importance of AI to business success

- Canadian executives display lack of trust in the technology: 48 per cent of Canada's early AI adopters cited "making the wrong strategic choice based on AI recommendations" as a top-three AI risk

- Just 51 per cent of Canadian executives believe AI will transform their company over the next three years (tied for the lowest rate among countries surveyed)

- Only 25 per cent embed AI into their products and services (the lowest rate)

Meanwhile—and we believe this is not a coincidence—72 per cent of Canadian respondents indicated they face moderate to extreme AI skill gaps.

This Report provides a data-driven snapshot of the changing demand for AI-related occupations and skills, comparing the years 2015 and 2018. It draws on TECHNATION analysis of exclusive commissioned job-posting data from Burning Glass Technologies, a Boston-based research firm; interviews and conversations with industry experts; and an investigation and analysis of emergent AI phenomena conducted by TECHNATION (see Appendix D for details on the methodology and limitations). The Report identifies what governments, educators and employers can do to strengthen the AI capabilities of Canada's workforce, from senior management to front-line employees.

If applied, the approaches recommended here will help enable Canadians and the Canadian economy to compete and thrive in the coming decade.

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2   Countries surveyed were Australia (100 respondents), Canada (300), China (100), Germany (100), France (100), United Kingdom (100) and United States (1100). Deloitte, Future in the balance? How countries are pursuing an AI advantage published May 1, 2019.

Rio Tinto: A mining industry AI leader

Rio Tinto is an international high-tech leader, pioneering AI-heavy technologies including driverless trucks and railway systems, and a pilot "Mine of the Future." Rio Tinto is building AI engineering and data science expertise to improve production and administrative processes in Canada and around the world.

Rio Tinto executives describe several challenges in AI talent sourcing, including high competition, lack of practical experience, and a rarity of key required skills. The company is taking steps to overcome these issues through in-house training and upskilling.

Read the full Rio Tinto case study, including the company's observations and recommendations, in Appendix B.

Canada: an AI adoption laggard?

AI has established its worth in many sectors. A 2019 McKinsey global survey of senior executives reported: [3]

- An overall 25 per cent year-over-year increase in AI use in standard business processes.

- Increased revenue from AI adoption for 63 per cent of respondents.

- Reduced costs due to AI adoption for 44 per cent of respondents.

According to McKinsey, "the results also show that a small share of companies—from a variety of sectors—are attaining outsize business results from AI, potentially widening the gap between AI power users and adoption laggards ."

For decades, Canadian companies have spent 40 per cent less per worker on tech (particularly computer software) than their US counterparts, a primary cause of the country's lagging productivity performance.[4]

Canada generally lags in adoption of new and emerging technologies. This is especially true of small and medium enterprises (SMEs) and industry sectors

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3   McKinsey & Company, "Global AI Survey: AI proves its worth, but few scale impact", November 2019.

4   Andrew Sharpe, "Understanding Canada's ICT investment shortfall." Centre for the Study of Living Standards, 2014.

A two-tier AI economy of leaders and laggards is emerging.

that are not intrinsically technological, such as construction, hospitality and government services. This gap is partly due to management's lack of technology-related knowledge, skills and confidence.

AI, a paradigm-shifting technology, exacerbates these challenges. While leading sectors like financial services and retail invest in AI, the rest of the economy risks falling behind. A two-tier AI economy of leaders and laggards is emerging.

Thirst for AI knowledge

Post-secondary education has seen an explosion in student demand for AI in computer science, engineering, life sciences, professional programs, and even the humanities. Colleges, polytechnics, universities and schools of continuing education are racing to grow AI faculties and programming.

Even faster growth is occurring in alternative pathways such as employer and vendor-supported AI training. Abundant online courses, publications and podcasts are available; many for free. They vary in technical and pedagogical quality.

But this growth in AI learning is not enough. **AI adoption across the economy depends on knowledge, skills, culture and operational changes across entire organizations,** and will require proactive cooperation among government, industry and educators.

What AI is—and is not

AI is the first human invention that can learn on its own.

▶ AI is the first invention that can continuously learn.

▶ AI excels at analyzing and classifying data to answer questions, make predictions and solve problems; it is used primarily for research, decision-making and automation.

▶ The technology is still in its infancy; yet its power and applications often surprise us.

▶ AI also entails profound risks and challenges: it is essential for all Canadians to understand and recognize them.

Traditional prescriptive software development remains the best and cheapest way to solve many problems. For example, prescriptive programming ensures that when you make a deposit at an ATM, the amount appears on your bank statement.

But for certain complex tasks—like interpreting an X-ray, driving a car or anticipating customer preferences—prescriptive programming is of no use. This is when AI and machine learning shine.[5]

Central to AI applications are algorithms. AI developers "train" an algorithm using collections of sample data that are similar to expected unseen data. The developer's job is to select and prepare this training data, try it out with various machine learning algorithms, modify or innovate the algorithms if necessary, and evaluate the results.

A successful algorithm can interpret comparable data to perform classification, prediction, anomaly detection and/or decision making. It can also be (somewhat) creative and use the information it gathers to improve itself. AI is the first human invention that can learn on its own.

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5   We use the terms machine learning and AI interchangeably to represent AI in its current forms, including deep learning and other variants.

It is essential for leaders, educators, policymakers—indeed, all Canadians—to understand what AI is, how it works, what it does, and what it means.

Powerful—yet limited—analysis and predictive capabilities

AI is used primarily for three kinds of tasks: research, decision-making and automation. It is regarded as the next big step in business analytics. AI is exceptionally good at analyzing and classifying data to answer questions, make predictions and solve problems. For example:

- Identifying if a photo is of a cat or a dog.

- Determining if a client is a credit risk.

- Ensuring the chatbot gives the best answer to a customer's question.

- Establishing what a self-driving car sees on the road, and how it should respond.

- Assessing a clinical image of a patient's retina.

Today's AI is powerful but limited. It exceeds humans in narrow, well-defined domains such as health diagnosis, credit risk assessment, machine translation, robotic warehouse management, or video game play.

AI is still in its early days, and as it evolves the technology will likely surprise us. It will certainly get better at learning. Broader "artificial general intelligence," if it ever comes to pass, will exceed the abilities of the human mind.

But AI is often oversold. AI lacks common sense, self-awareness or an understanding of cause and effect. Every AI tool that is currently deployed focuses on a narrow topic such as face recognition or customer interaction.

AI also entails risks and challenges, including the displacement of skills and jobs, bias, deception, data control and privacy, military and social control, and economic inequality.

Because of these profound implications, it is essential for leaders, educators, policymakers—indeed, all Canadians—to understand what AI is, how it works, what it does, and what it means for them, their careers, families, friends and communities. Every Canadian must be armed with AI literacy, job-relevant AI skills, and awareness of how to maximize its benefits and deal with its risks and pitfalls.

AI skills demand in Canada: a snapshot

AI is no longer the sole domain of software developers and data scientists.

► Demand for AI skills is increasing: from 2015 to 2018, Canadian AI job postings increased by 211 per cent across a broad range of sectors.

► AI education-related job postings increased by 351 per cent.

► This growth is not strong enough, however, to move AI into the mainstream. Smart demand needs to be encouraged through awareness building and AI education for executives and senior managers.

► AI skills are not mere add-ons to traditional occupations; jobs need to be redefined in light of machine learning and data science.

► The most in-demand AI skills are machine learning, data science and predictive modelling.

Demand for AI talent is expanding quickly in Canada. From 2015 to 2018, Canadian AI job postings increased by 211 per cent, to 6,047. AI is no longer the sole domain of software developers and data scientists. Employers are beginning to seek AI skills in marketing and product managers, financial analysts, sales managers, market researchers, risk manager/analysts, project managers, statisticians, human resources/labour relations specialists and many others.[6]

Important methodological note:
To qualify as an AI position for this Report, an advertised job posting must include at least one AI skill per a list developed jointly by TECHNATION and Burning Glass. For example, 116 of 644 job postings for actuaries in 2018 stipulated one or more AI skills. We define these 118 postings (18% of all postings for actuaries) as AI hybrids.

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6   Numbers of AI job postings for these jobs ranged from a high of 82 (marketing managers) to 36 (human resources/labour relations specialists).

TECHNATION AI jobs and skills framework

AI Technology **AI Hybrid** **AI Educators**
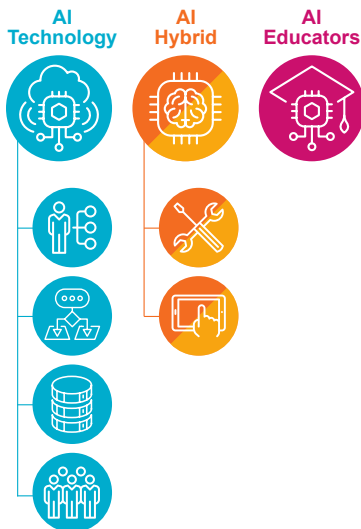
► To address this changing landscape, the *TECHNATION AI Jobs and Skills Framework* provides a starting point for workforce planning, skills development and labour market analysis. The Framework draws on TECHNATION analysis, AI sector consultations and commissioned employer demand data from Burning Glass data. It can help employers, educators and governments make informed decisions regarding AI workforce development, occupational standards, and labour market research.

► Appendix A provides more details on the Framework, including demand data for occupations and job-related skills.

The Framework consists of three occupational categories—AI Technology, AI Hybrid, and AI Education—that encompass six different job families (Table 1):

■ **AI Technology Category**: Over half the postings per 2018 Burning Glass data were for jobs dedicated to AI technology including the job families of *AI business technology managers (AIBTM)*, *software developers and engineers*, *data professionals, and interaction designers*; these job postings shot up 239 per cent. Meanwhile, employment in comparable IT jobs grew by 16 per cent, and overall Canadian employment grew just four per cent.[7]

■ **AI Hybrid Category**: Most of the other AI postings were for AI hybrid skill sets including *AI data-intrinsic jobs* and *AI data user jobs* (see page 17 for details). Employers are beginning to look for AI skills in many different occupations, from actuaries to financial analysts to urban planners. From 2015 to 2018, this demand increased by 175 per cent, to 2483 postings in 203 occupations.

■ **AI Education Category**: Just three per cent of the job postings were for AI education-related positions, however, this sector showed the sharpest growth, at 351 per cent.

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7   The comparable TECHNATION list of IT occupations consists of computer and information systems managers (National Occupational Classification 0213), information systems analysts and consultants (2171), database analysts and data administrators (2172), software engineers and designers (2173), computer programmers and interactive media developers (2174), and web designers and developers (2175). Statistics Canada data analysis by Labour Market Information Council.

Table 1:

Demand growth for AI jobs

Category or family	2015 postings	2018 postings	2015/2018 growth in postings	2015 share of all AI postings	2018 share of all AI postings
AIBTM family	158	603	282%	8%	10%
AI Development family	411	1,336	225%	21%	22%
AI Data family	381	1,296	240%	20%	21%
AI Interaction family	55	171	211%	3%	3%
Subtotal: AI Technology	**1,005**	**3,406**	**239%**	**52%**	**56%**
AI Data-intrinsic hybrid family	579	1,496	158%	30%	25%
AI Data-user hybrid family	323	987	206%	17%	16%
Subtotal: AI-Hybrid	**902**	**2,483**	**175%**	**46%**	**41%**
AI Education family	35	158	351%	2%	3%
Subtotal: AI Education	**35**	**158**	**351%**	**2%**	**3%**
TOTAL	**1,942**	**6,047**	**211%**	**100%**	**100%**

Source: TECHNATION analysis of Burning Glass job posting data

Appendix A includes employer-specified top-25 skills for 16 representative AI Technology and AI Hybrid occupations.
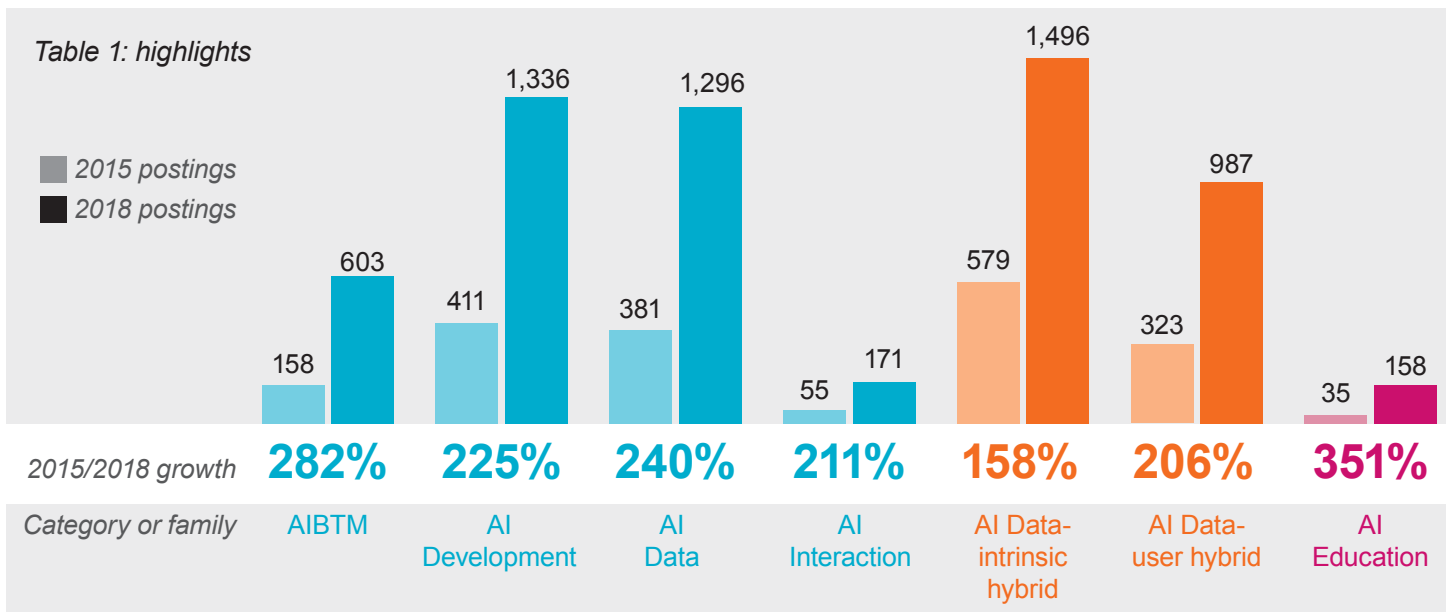
Table 1: highlights

	2015 postings	2018 postings

2015/2018 growth	282%	225%	240%	211%	158%	206%	351%
Category or family	AIBTM	AI Development	AI Data	AI Interaction	AI Data-intrinsic hybrid	AI Data-user hybrid	AI Education

AI technology occupational category

The AI Technology-focused occupational category includes four job families:

- **AI Business Technology Management (AIBTM)** professionals ensure alignment between business needs and AI solutions. These include jobs like chief information officer, systems analyst, IT project manager and technology consultant. Besides education jobs, AIBTM is the fastest growing AI occupational family. The 282% jump in demand for AIBTM professionals from 2015 to 2018 suggests that AI is moving from visionary labs to business practicalities. But the 2018 volume (603 postings) and demand share (13 per cent of AI technology postings) for AIBTM professionals are insufficient for AI to move from research to the mainstream.

- **AI development professionals** (e.g. software engineer/developer, technology architect, computer scientist) focus on algorithmic research, design, development and implementation. They do advanced work at the frontiers of deep learning and cognitive computing. Their skills may also include computer vision, neuroscience and physics.
  Demand for *non-AI* software developers/engineers is robust but dropped 10 per cent in 2018 from 2015, indicating that demand for software development and engineering is shifting from traditional skills toward AI.

- **AI data professionals** include data scientists, data/data mining analysts, data architects and data engineers. To use packaged AI services in a business environment, few projects need advanced AI software engineering skills. Instead, they need data scientists and other data professionals to organize and feed corporate data into packaged AI services. As with AIBTM, 2015-2018 demand growth for AI data professionals, while impressive, was too slow for pervasive AI adoption. Anecdotal information suggests that demand for AI data skills has continued to accelerate since 2019.

- **AI interaction designers** work to ensure the usability and accessibility of AI work products (e.g. web developer and designer, user interface/usability designer).

The 2018 volume and demand share for AIBTM professionals are insufficient for AI to move from research to the mainstream.

> "Rather than armies of PhDs, most organizations need broad data science literacy, access to off-the-shelf and embedded AI tools, and cultures of innovation and experimentation."

Deloitte: AI consulting leverages the cloud

Omnia AI is Deloitte Canada's 500-person strong AI practice. Omnia produces industry-specific AI solutions to complement the firm's client services, addressing contract management, physician workflow, infrastructure risk management, cybersecurity and digital-media risk monitoring, among other areas.

Omnia relies heavily on available cloud-based AI capabilities, deploying in-house algorithm design only when necessary. Says Deloitte Managing Partner Steve McCaughey: "Rather than armies of PhDs, most organizations need broad data science literacy, access to off-the-shelf and embedded AI tools, and cultures of innovation and experimentation." Deloitte reports challenges in finding suitable AI candidates, particularly with relevant experience; executives point to a lack of AI undergraduate courses and programs as a key concern. The company works actively with educational institutions to improve the AI skills landscape.

Read the Deloitte case study in Appendix B.
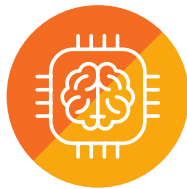
AI-hybrid occupational category

AI-hybrid occupation postings require AI skills for jobs that are not inherently AI-oriented (e.g. data science skills for a medical research job). AI hybrid jobs include a surprising variety of job roles and levels ranging from senior management to front-line workers. In 2018, 41 per cent of AI postings combined other business or technical skill sets with AI. We have assigned AI hybrid jobs into two families:[8]

1. **AI data-intrinsic hybrids** like business intelligence, financial analysis and marketing analysis. These jobs entail hands-on work with AI-based analytics, including mid-to advanced-skilled data management and programming. Following are some examples, including numbers of postings in 2018:

Business intelligence analyst	208	postings
Actuary	116	postings
Cybersecurity engineer/analyst	92	postings
Fraud examiner/analyst	31	postings
Logistics/supply-chain analyst	6	postings

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8   Caveat: as noted earlier, our placement of occupations within one or the other hybrid family was based on suppositional assessment of the various titles. It is therefore open to review.

2. **AI data-user hybrids** like product management, human resources and retail store management. These jobs require sufficient AI literacy to knowledgeably lead or function in an AI-enabled environment and entail basic data management and setting application parameters. Examples include:

Marketing manager	82 postings
Human resources manager	30 postings
Medical scientist	21 postings
Production plant manager	8 postings
Manufacturing machine operator	7 postings
Automotive service technician/mechanic	5 postings

Job posting analysis reveals that AI skills are not mere add-ons to traditional occupations. Rather, skill profiles in dozens of sectors and business functions are being redefined in light of machine learning and data science.
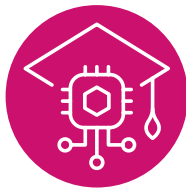
AI education occupational category

Demand for **AI educators** grew 351 per cent from 2015 to 2018, with 158 job postings in 2018. Of these, 90 were for college professors and instructors. Another 24 were for private-sector AI trainers—up from zero demand in 2015. The balance of AI education postings was for guidance counsellors and administrators.

> For Canada to achieve economy-wide AI leadership, complex cognitive skills should be at or near the top of the priority list for all learners.

Overall top skills for AI, including distinctive essential skills

The most in-demand AI skills (Table 2) are machine learning and data science, followed by artificial intelligence (as a generic skill) and predictive models. As employers became more sophisticated over the 2015-18 period, they increased their requirements from one AI skill to several. Other technology skills in wide demand for AI jobs are SQL and Java.

Essential skills, particularly communication and collaboration, comprise six of the top 15 skills in demand for AI jobs. The other in-demand essential skills for AI are complex cognitive skills: research, problem solving, creativity and planning. It is worth considering that, for Canada to achieve economy-wide AI leadership, complex cognitive skills like these should be at or near the top of the priority list for all learners.
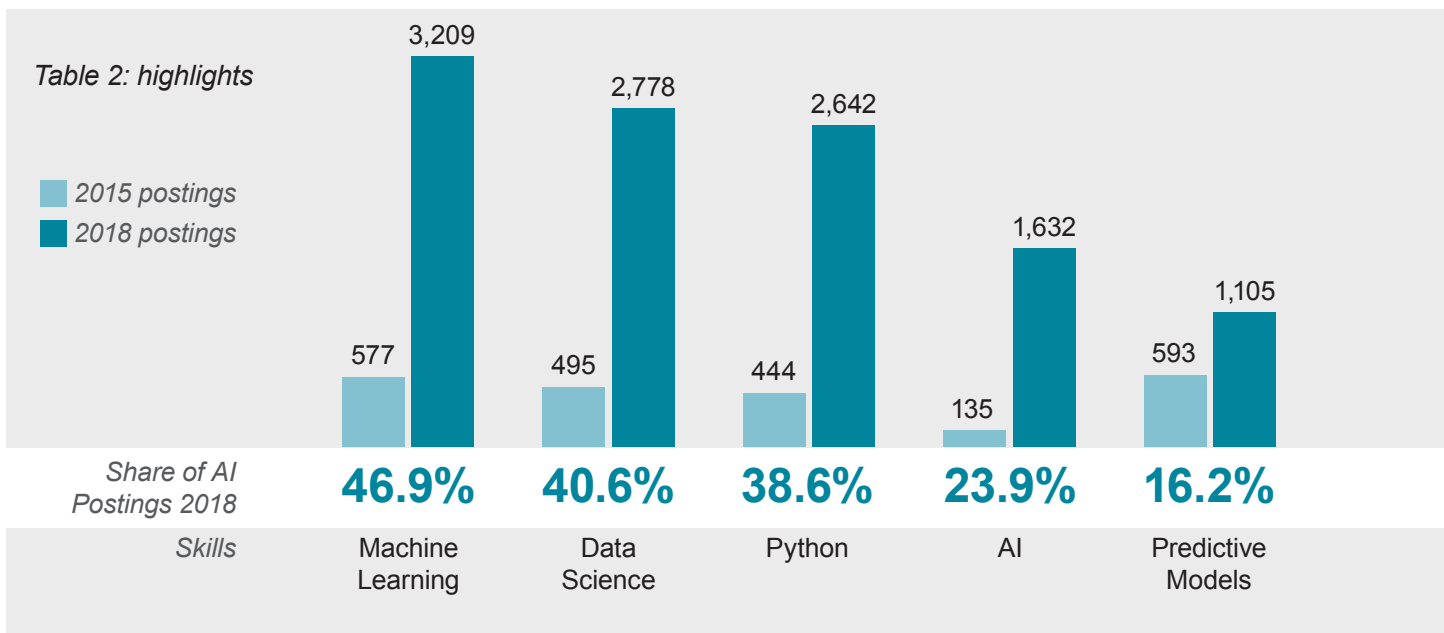
For more detail on in-demand skills for specific AI job roles, see the
TECHNATION AI Jobs and Skills Framework, Appendix A.

Table 2:
Top 15 in-demand skills: all AI occupations

| | Core AI skill | | Other technology skill | | Essential/baseline skill |
| AI adjacent skill | | Technical skill | |

Skill	Postings 2015	Postings 2018	Share of AI Postings 2015	Share of AI Postings 2018	Change
Machine Learning	577	3,209	26.0%	46.9%	20.9%
Communication Skills	1,053	3,171	47.5%	46.4%	-1.1%
Data Science	495	2,778	22.3%	40.6%	18.3%
Python	444	2,642	20.0%	38.6%	18.6%
Teamwork / Collaboration	724	2,617	32.6%	38.3%	5.6%
SQL	790	2,232	35.6%	32.6%	-3.0%
Research	689	2,123	31.1%	31.0%	0.0%
Problem Solving	626	1,899	28.2%	27.8%	-0.5%
Artificial Intelligence	135	1,632	6.1%	23.9%	17.8%
Big Data	387	1,518	17.4%	22.2%	4.7%
Software Development	425	1,515	19.2%	22.1%	3.0%
Java	436	1,451	19.7%	21.2%	1.6%
Creativity	388	1,357	17.5%	19.8%	2.3%
Planning	425	1,316	19.2%	19.2%	0.1%
Predictive Models	593	1,105	26.7%	16.2%	-10.6%

Source: TECHNATION analysis of Burning Glass job posting data

Table 2: highlights

2015 postings
2018 postings

	Machine Learning	Data Science	Python	AI	Predictive Models
Share of AI Postings 2018	**46.9%**	**40.6%**	**38.6%**	**23.9%**	**16.2%**

Challenges to AI growth in Canada

► The demand for AI skills is ill-distributed; some sectors and firms are leaders in AI adoption, others lag far behind. The result: an emerging two-tier AI economy.

► Public sector organizations are underinvesting in AI.

► In many sectors and organizations, limited management awareness and leadership results in insufficient demand for AI talent.

► Mainstream AI adoption requires more data scientists than AI researchers and engineers. However, demand for the two job categories is approximately equal.

► Not enough schools deliver AI courses and programs to meet demand; this is limited by not enough available AI educators.

► Upskilling from a traditional (non-AI) technical career into an AI-focused one can be challenging, requiring new skills and new ways of working. Upskilling supports are needed.

TECHNATION research identified several skills-related challenges to AI adoption and growth. These are described in the following sections.

Five of Canada's 20 industry sectors account for over 80 per cent of demand for AI technology professionals.

Challenge 1: Lack of sectoral & occupational breadth

In nearly every sector, AI-related job postings between 2015 and 2018 increased more than 250 per cent. However, demand for AI skills is ill-distributed: **while some sectors and firms lead in AI adoption, others lag significantly, resulting in a two-tier AI economy.**

Five of Canada's 20 industry sectors account for over 80 per cent of demand for AI technology professionals: finance and insurance; professional, scientific and technical services (PS&T); information; manufacturing; and retail.

Other economically significant sectors, however, appear to lag in AI adoption. They include (listed from weakest AI demand):[9]

Agriculture, forestry, fishing and hunting	11 postings
Accommodation and food services	17 postings
Wholesale trade	21 postings
Construction	22 postings
Utilities	27 postings

Internationally, every one of these sectors is being transformed by AI-based applications and business models.

The Canadian public sector, too, is underinvesting in AI, including public administration at all levels of government, crown corporations, education and health care.

Demand for AI professionals is also skewed within sectors. For example, in 2018 six finance and insurance firms posted over 50 per cent of AI job opening in their sector; five global tech firms posted over 50 per cent of AI-related job openings in the information sector.

As noted earlier, AI Hybrid job roles are proliferating. However, of 2,320 postings for 203 different hybrid jobs, 44 per cent are for the top 10.

Just six of 1,356 postings for CEOs required AI knowledge.

Challenge 2:
Insufficient AI-literate business leadership

We identified insufficient demand for AI leadership skillsets in Canadian business organizations, indicating a lack of intentional AI use.

To lead in AI-based business transformation, most, if not all CEOs and senior managers should have AI awareness. But in 2018 job postings:

- Just six of 1,356 (0.004%) postings for CEOs required AI knowledge

- Twenty-six of 3,578 (0.007%) postings for general managers required AI knowledge

For the Canadian economy to pick up its pace, demand for executives

9   We know anecdotally that some firms in these sectors are aggressively building AI teams. As discussed elsewhere, this report provides trend data. Actual numbers hired are greater than reported here. For more details see Appendix D, Methodology and Limitations.

and managers with AI knowledge and skills must increase. Executives, managers—even board members—need to understand what is new and different about a commitment to AI. Organizations must combine ambition with realism in identifying and prioritizing viable AI-use cases.

An AI-enabled company governs, organizes, manages and deploys data enterprise-wide as a core value-driving asset. This move away from treating data as a dispersed collection of business records requires committed investments in cultural, organizational and technology change.

AI success entails building trust and collaboration from everyone from senior executives to technologists and front-line personnel. Leaders must ensure the organization is on top of AI-related challenges such as job impacts, upskilling, ethical use, privacy, data ownership and unintended consequences.

The 2018 volume and demand share for AIBTM professionals are too low for AI to move from research to the mainstream.

Challenge 3:
Insufficient demand for AI Business Technology Management (AIBTM) professionals

BTM professionals ensure that technology investments are wisely chosen, appropriately designed and effectively implemented.[10] BTM jobs include IT executives and team managers; analysts and consultants; product, project and program managers; and business development/sales managers.

BTM professionals with AI skills (i.e., AIBTM) are critical to AI success in any organization. Postings for AIBTM jobs increased 282 per cent from 2015 to 2018, faster than for AI developers (225 per cent) and data scientists (240 per cent). However, the 2018 volume (603 postings) and demand share (13 per cent) for AIBTM professionals needs to triple for AI to move from research to the economic mainstream.[11]

economic mainstream

3X
current volume
& demand share

current
levels

AIBTM
current volume
& demand share

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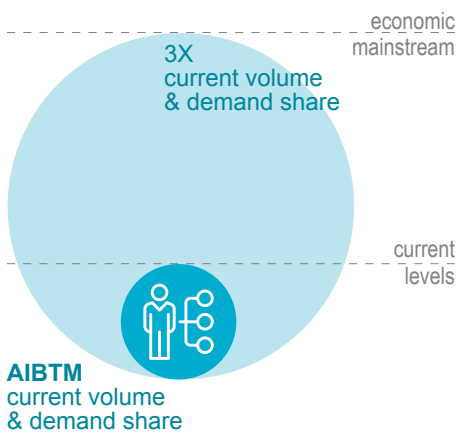
10   Business Technology Management (BTM) is a rapidly growing professional field that addresses alignment of technology outcomes with business requirements. A TECHNATION predecessor, in partnership with a group of leading educators and employers, launched a national, accredited BTM post-secondary initiative in 2009. Approximately 30 institutions across Canada now offer BTM programs, in both official languages. They span colleges, universities (from undergraduate to Ph.D.) and continuing education. We have coined the concept of AIBTM as a focus area of BTM in this paper.

11   For comparison, some 300,000 traditional BTM jobs comprise 45 per cent of comparable technology jobs in Canada. The other jobs in this grouping include software developers and engineers, computer programmers, database analysts and the like. Based on Labour Market Information Council analysis of 2018 Statistics Canada Labour Force Survey data.

Mainstream businesses need many more AI data scientists than AI software engineers.

Challenge 4:
Filling the data science (and scientists) gap

AI researchers, software engineers and designers are in high demand. But today's cloud-based applications increasingly commoditize AI capabilities. As a result, most companies don't need to create AI tools in-house. They do, however, need to organize and deploy their enterprise data to feed AI technologies for their specific needs.

Across the economy, the marketplace needs more data science than algorithmic research and development skills. Working with AI-literate business users, data science professionals with good AI knowledge are the key to cost-effective deployment of off-the shelf AI toolkits.

Conclusion: mainstream businesses need many more AI data scientists than AI software engineers. Yet in 2018, demand for the two job categories was approximately equal. As with AI-literate executives, managers and AIBTM professionals, demand for data scientists is insufficient to meet anticipated business needs. Yet opinion leaders and media tend to promote AI research and engineering careers without appreciating that data science is a bigger part of the future.

Industry jobs are often better-paid and more professionally rewarding than academic positions.

Challenge 5:
AI education capacity

The student AI/data science pipeline is far from meeting the needs of employers and the economy.

University and college capacity to meet AI skills demand is stretched. AI courses and programs have long waiting lists and crowded classrooms. Schools have aggressively expanded class sizes and are trying to hire new faculty and launch new courses and programs. Finding and hiring qualified AI educators can be difficult; industry jobs are often better-paid and, for many, more professionally rewarding than academic positions. This at a time when we need more dedicated data science, computer and engineering programs, as well as programs in the application of AI technologies across all curricula. To succeed in this emerging economy, graduates of nearly all programs need a solid basic understanding of AI and its applications to their discipline.

Only seven of Canada's 81 public universities (University of British Columbia; Simon Fraser University; University of Alberta; University of Waterloo; University of Toronto; Université de Montréal; and McGill University) offer broad portfolios of undergraduate and graduate AI and/or data science

Not enough schools deliver AI courses and programs, and this is further limited by not enough available AI educators.

courses and programs.[12] Eight additional universities offer graduate programs and three or more undergraduate AI courses. That leaves 66 universities with limited to no AI content.

Colleges and polytechnics, typically more agile and aligned to employer needs, are moving quickly into machine learning and, increasingly, data science education. As well, AI learners have many alternatives to traditional public education, from employer-supported upskilling to free or inexpensive online courses, many of which have appeared to fill the gap in institutional AI education.

The bottom line is this: not enough schools deliver AI courses and programs, and this is further limited by not enough available AI educators.

Just 15
of Canada's 81 public universities offer moderate to broad AI education

Dawson College: AI for everyone

Montreal's Dawson College is the first Canadian post-secondary institution to declare that every graduate should achieve a level of AI literacy. The intent is to equip all graduates with discipline-relevant AI concepts, appreciation of societal issues such as AI ethics, and occupational skills for AI-enabled work. Many will have hands-on AI technical experience.

While it will take years to implement the AI strategy across all multi-year programs, the first classroom steps were unrolled in 2019-20, bringing basic AI to all students in the short-term by including AI in general education courses, mandatory for all CEGEP students. AI tools are also being introduced to improve student success and access to services, and to improve classroom pedagogy.

Read the full Dawson College AI education case study in Appendix B.

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12   TECHNATION online research was conducted in February 2019. Our apologies for any schools or programs that we may have missed.

An AI approach to hybrid jobs could be entirely different from a traditional approach.

Challenge 6:
Upskilling for AI

Upskilling for AI presents challenges, especially for top technical occupations.

- To become a machine learning specialist, a typical traditional software developer/engineer needs to gain expertise in machine learning, statistics, unstructured data and several unfamiliar programming languages—along with new ways of thinking and working. AI work is more about research and experimentation than pre-design and specification: a very different mindset from traditional programming.

  On the other hand, some technical skills, as well as many essential skills practiced by non-AI software developers/engineers are transferable to AI. Some non-AI developers and engineers will make the transition easily. Others will take advantage of the growing commoditization and embeddedness of AI tools. Over the medium-term, software development and engineering work will change in ways that are hard to predict.

- As for data science, this is an emerging field that combines data analysis, statistics, specialized software and machine learning for large datasets. Furthermore, it requires use of these techniques to perform complex analysis and machine learning design. Some data analysts will be able to upskill into data science roles. But this will be a stretch for traditional database architects and managers. This gap will pose challenges for organizations that aim to transform their data from scattered collections of records to corporate-managed competitive assets.

- Similar challenges apply to AI data-intrinsic hybrid occupations such as business analysts, cybersecurity engineers and medical scientists. An AI approach to these hybrid jobs could be entirely different from a traditional approach. For AI user hybrid occupations—such as marketing manager or human resources professional—upskilling may be easier.

Recommendations

Following are specific recommendations to support an AI skills roadmap for Canada, based on the findings of this Report.

Government

1. Policymakers should define and action AI literacy as an essential skill for all Canadians.

2. Federal, provincial and municipal governments should mandate AI centres of excellence to develop and implement cross-government strategies for AI and data science skills development. This should include:
    - Government employee training and skill development at all levels.
    - Policies and programs for government-wide data management.
    - Investments in high-impact AI pilot projects.

3. Labour market information research, including occupation and skills classifications, should be expanded to incorporate AI-related taxonomies. This will enable employers, planners, career choosers and educators to make informed decisions about workforce development, education and training investments, and job transition support. This should include:
    - Designating AI software developer/engineer, data scientist and related occupations as national occupational classifications, with associated skill and competency models.
    - Tracking of AI-related skills supply and demand across the spectrum of occupations.
    - Working with post-secondary institutions and employers to define competency standards and learning outcomes for emerging AI-related occupations.

Government and Industry

4. Governments and employers should conduct a national campaign to promote data science organizational capabilities and workforce skills development, broadly targeting employers, career seekers, career influencers and educators.

5. Industry associations, the information and communications technology sector and governments should draw on the TECHNATION AI Jobs and Skills Framework and related tools to educate employers regarding AI staffing strategies.

6. Industry organizations and governments should partner to accelerate AI skills and capability development, particularly in lagging sectors, small and medium-sized enterprises, non-profits and government entities such as healthcare institutions and crown corporations.

Industry

Organizations must combine ambition with realism in identifying and prioritizing viable AI-use cases, perhaps with the assistance of external expertise.

7. Public, private and non-profit organizations should prioritize AI education for board governance, senior and front-line management, including machine learning and data science concepts and implications for action. This will help address the insufficient demand for skillsets that are essential to adoption and deployment of AI in business.

8. Public, private and non-profit organizations should invest in AI upskilling requirements assessment and implementation for front-line technical *and* non-technical occupations.

9. AI upskilling of traditional software developers/engineers and data professionals should be customized to job requirements and employee capabilities.

10. Organizations should launch AI pilots that include technical and non-technical personnel in learning and implementation. A small but impactful first project is a good way to get the organization's AI learning journey started. This may be a valuable opportunity to engage external expertise. Key skills and learning steps in this journey include:
    □ Learning how to formulate problems (use cases) that AI can solve.
    □ Clarifying cultural, process, organization and staffing needs, including unique requirements in various parts of the organization.
    □ Getting on top of AI-related risks and challenges such as building confidence in AI-based approaches, their impact on jobs and skills, and developing new modes of collaboration and systems design.
    □ Implementing policies, culture and processes for privacy and data ownership, algorithmic and data bias, security and other ethical issues.
    □ Supporting machine learning methods including repeated trial and

error and ongoing collaboration among technologists, decision-makers and users. This necessitates patience and risk tolerance.

▫ Teamwork, collaboration, communication, creativity and problem solving are essential skills for AI leadership and success.

11. Industry associations in all sectors should work with their members and stakeholders to develop AI awareness, skills and exemplary AI projects.
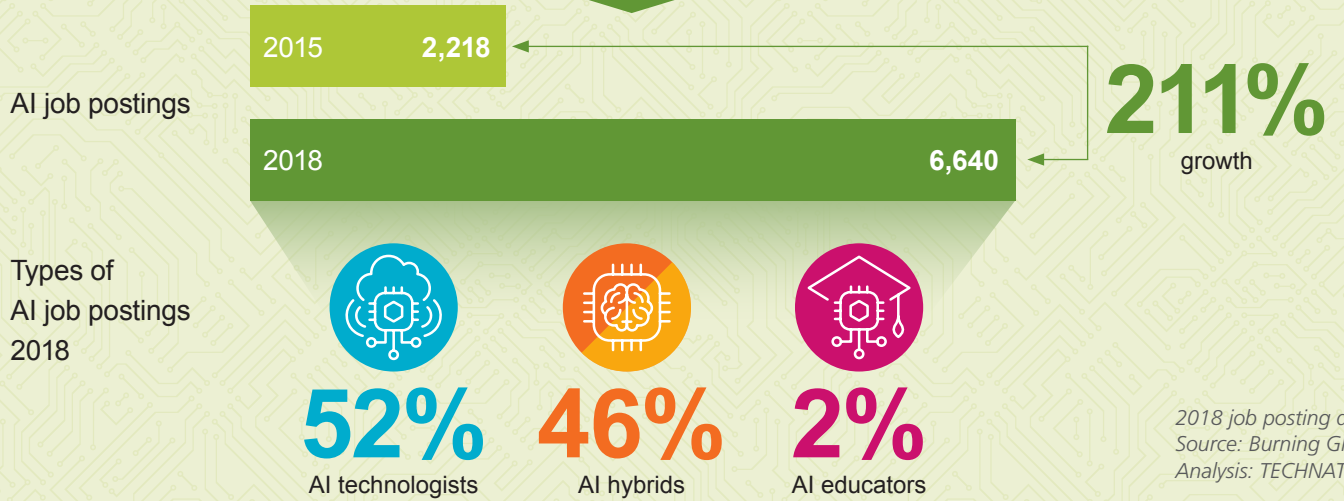
Educators

Many students and educators lack awareness of the nature and breadth of work and career opportunities in this exciting, rapidly growing field. Changing this will take efforts focused at all levels of education. Appendix A provides insight into the skills required for AI occupations.

12. AI and data science knowledge, skills, personal and societal implications should be taught appropriately at all education levels and programs, in all disciplines and fields, including K-12, post-secondary and adult education. Graduates of nearly all programs need basic AI understanding.

▫ AI education should address ethical and risk issues such as displacement of skills and jobs; bias; deception; data control and privacy; military and social control; and inequality.

13. Public education initiatives promoting AI-related careers and skills development should emphasize opportunities for AI business technology management (AIBTM), data scientists and high-potential hybrid AI skill sets—in addition to AI researchers, engineers, and developers.

14. AI teaching capability development for all disciplines and programs should be a priority for public education at all levels. Student advisers should also receive education about AI-related career options and pathways.

15. All business education programs should integrate AI. Business technology management programs should be redesigned to incorporate thorough AI education and skills development.[13]

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13   The Business Technology Management post-secondary programs build on a national TECHNATION initiative to address the need for business/technology hybrid skill sets.
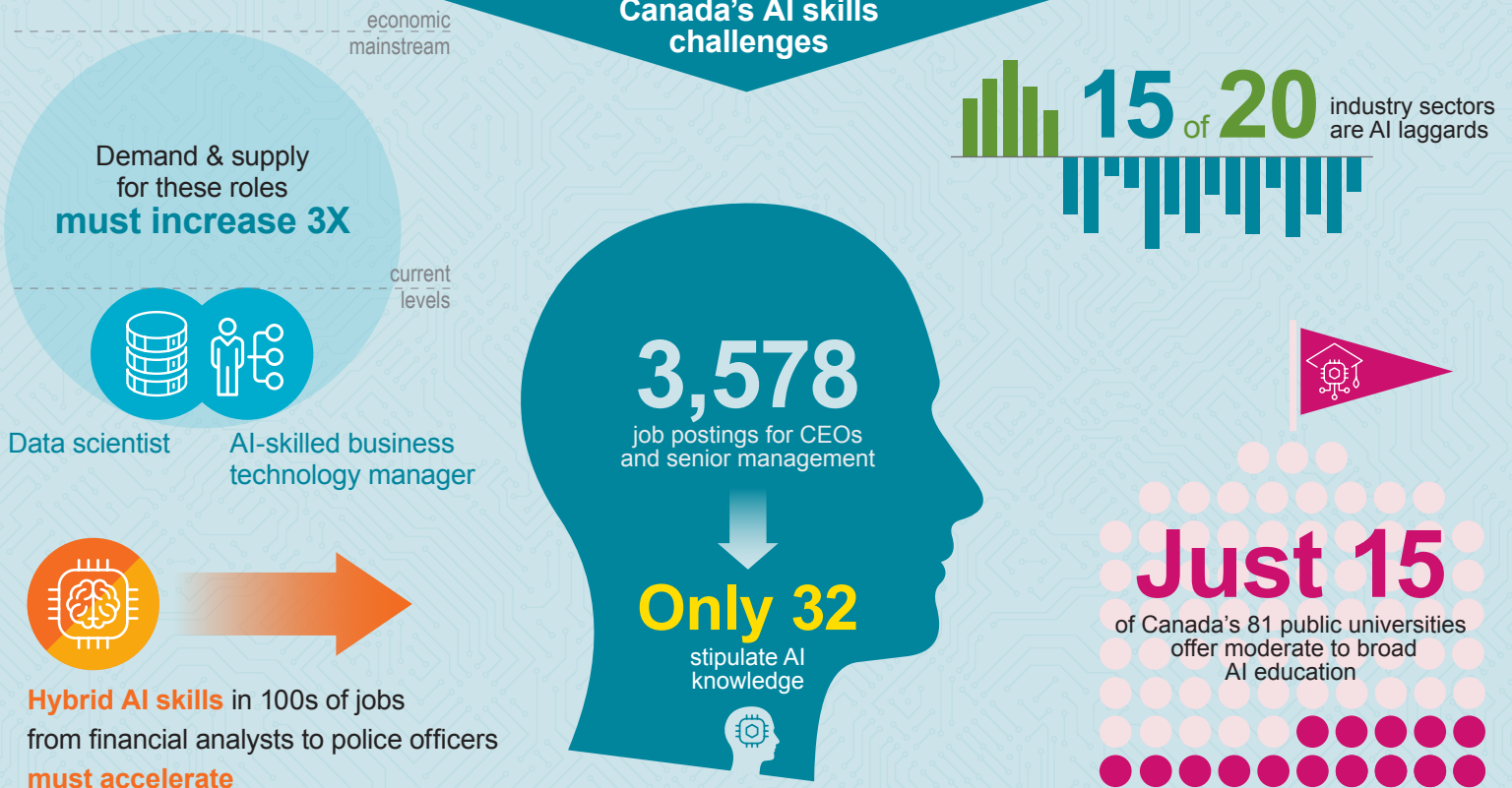
Roadmap to AI success across Canada's economy

Growing demand for AI skills

AI job postings

| 2015 | 2,218 |
| 2018 | 6,640 |

211% growth

Types of AI job postings 2018

52% AI technologists

46% AI hybrids

2% AI educators

2018 job posting data. Source: Burning Glass. Analysis: TECHNATION.

▶ Canada punches above its weight in AI research & innovation

▶ AI R&D skills drive explosive growth of entrepreneurship & investment

▶ Key sectors like finance, manufacturing & retail making transformational AI investments

Canada's AI skills challenges

economic mainstream

Demand & supply for these roles **must increase 3X**

current levels

Data scientist

AI-skilled business technology manager

Hybrid AI skills in 100s of jobs from financial analysts to police officers **must accelerate**

3,578 job postings for CEOs and senior management

Only 32 stipulate AI knowledge

15 of **20** industry sectors are AI laggards

Just 15 of Canada's 81 public universities offer moderate to broad AI education

Priorities: Skill Canadians for the AI economy

▶ AI-upskill executives & managers

▶ Bring AI skills and knowledge to all STEM, professional, arts & humanities education
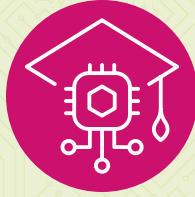
▶ Expand AI education in business administration, business technology management, data science

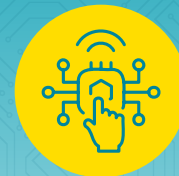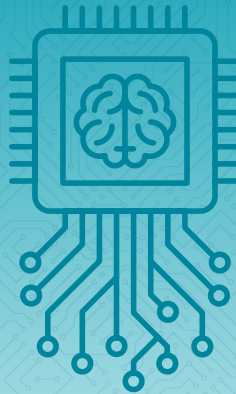▶ Bring AI career and skill awareness to employers, educators, students, parents, & career counsellors

▶ AI-upskill professional & front-line workers

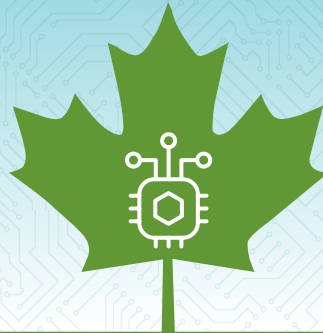▶ Track demand & supply for AI skills across the economy

AI for everyone

AI is the first human invention that learns on its own. **It brings opportunities and risks** to Canadians and their communities.

Every Canadian must understand what AI is, how it works, what it does and what it means for them.

Define and action AI as an essential skill for all Canadians!

Conclusion

AI adoption across the economy depends on knowledge, skills, culture and operational changes across entire organizations.

While further research is required and ongoing, this Report provides an early snapshot of where Canada stands in AI adoption through the lens of skills demand. All indications are that government and industry are at a critical crossroads.

This Report describes rapidly growing employer demand for AI skills; but the demand is ill-distributed across economic sectors and firms. The skills that employers seek are not always the ones they need for contemporary AI workforce design. Meanwhile, many students and educators lack awareness of the nature and breadth of career opportunities in this exciting, rapidly growing domain. These things must change for Canada to compete effectively in the next decade.

Now is the time to take deliberate actions to ensure that every organization, workforce participant, and citizen has the wherewithal to succeed in the AI era—and that Canada remains competitive in the post-COVID economy. This document provides a first roadmap for how to get there.

Appendix A: TECHNATION
AI Jobs and Skills Framework

The skills that employers seek for AI jobs

AI Technology **AI Hybrid** **AI Educators**
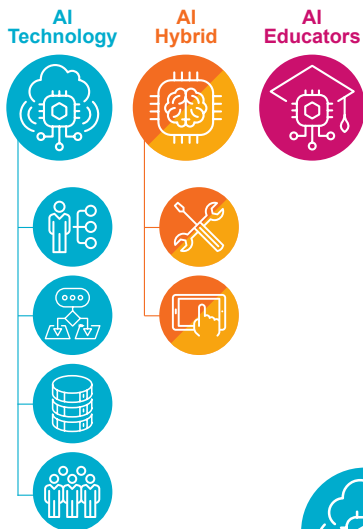
The *TECHNATION AI Jobs and Skills Framework* is a starting point for Canadian workforce planning, skills development and labour market analysis.

The Framework includes three sets of AI occupational categories (**AI Technology**, **AI Hybrid** and **AI Educators**) which encompass six different occupational families. It also lists the top-25 in-demand skills for 17 representative AI Technology and AI Hybrid occupations, based on employer demand. TECHNATION invites comments and suggestions from all stakeholders regarding this initial model.

1. **AI Technology-focused occupational families**, which contain occupations that focus on technology management, design, development and implementation (e.g., AI business analysts, engineers, data scientists). The AI Technology category includes four job families:

   a) **AI Business Technology Management (AIBTM)** professionals ensure alignment between business needs and applications of AI technologies. Increasingly, postings for BTM roles specify AI-related skills. These include jobs like chief Information officer, systems analyst, IT project manager and technology consultant. Other than Education, AIBTM is the fastest growing AI occupational family (Table 3).

   b) **AI Development jobs** focus on algorithmic research, design, development and implementation (e.g. software engineer/developer, technology architect, computer scientist).

   c) **AI Data professionals** organize, prepare and run data through machine learning models to experimentally solve business problems. Roles include data scientists, architects, engineers and analysts. Data Science occupation demand growth (282 per cent for 2018 over 2015) is significantly ahead of AI Development (240 per cent).

d) **AI Interaction designers** work in concert with other team members to ensure the usability and accessibility of AI work products (e.g. web developer and designer, user interface/ usability designer).

2. **AI Hybrid** occupation families include postings where employers stipulate AI skills for jobs that are not specifically AI-oriented (e.g., where a posting requires data science skills for a medical research job). AI Hybrid itself includes two job families:[14]

a) **AI Data-intrinsic hybrids** like business intelligence, financial analysis and marketing analysis (37 occupations in 2018). These jobs entail hands-on work with AI-based analytics, including mid- to advanced-skilled data management and programming.

b) **AI Data-user hybrids** like product management, human resources and retail store management (169 occupations in 2018). These jobs require sufficient AI literacy to knowledgeably lead or function in an AI-enabled environment. They entail basic data management and setting application parameters.

3. Demand growth for **AI Educators**, including faculty, administrators and career counsellors, is higher than for any other segment at 351 per cent.

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14   Caveat: our placement of occupations within one or the other hybrid family was based on suppositional assessment of the various titles. It is, therefore, open to further review.

BTM professionals ensure that technology investments are chosen wisely, designed appropriately and implemented effectively.

AI Business Technology Management

Business technology management (BTM) refers to jobs that ensure alignment between IT and business needs. BTM is a generic concept that applies to all aspects and areas of technology. BTM professionals ensure that technology investments are chosen wisely, designed appropriately and implemented effectively, in accordance with business needs. BTM skill sets are pertinent to all organizations, whether buyers or sellers of technology. The jobs include IT executives and managers; analysts and consultants; product, project and program managers; and business development/sales managers (See Appendix C for Burning Glass occupation definitions).

The most in-demand AI-related BTM jobs (AIBTM) in 2018 were business/management analyst, IT project manager, systems analyst, product manager and business development/sales manager (Table A-1).

Table A-1
Top 8 AIBTM job postings

AI BTM Job Title	2015	2018	Share of all postings for occupation (2018)
IT Project Manager	44	112	2%
Systems Analyst	19	98	1%
Product Manager	15	82	3%
Business Development / Sales Manager	18	60	0.5%
Technology Consultant	8	55	6%
Project Manager	17	46	0.5%
Engineering Manager	10	43	2%
CIO/ Director of IT	9	32	3%

Source: TECHNATION analysis of Burning Glass job posting data

All AIBTM roles require complementary hard and soft skill sets (Table A-2). Nearly all seek skills in machine intelligence, data science, communication, problem solving, teamwork and programming languages (Python in particular). But the differences among occupations are significant. Each occupation skills demand profile includes distinctive hard and soft skills.
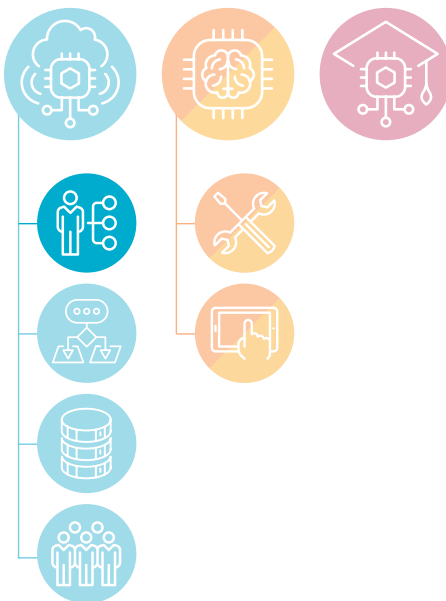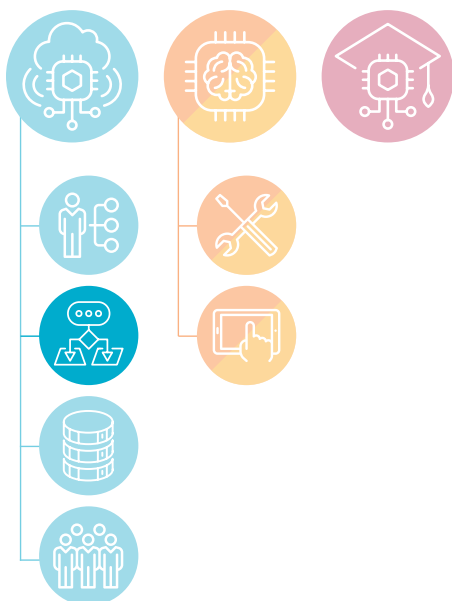
Table A-2

Top 25 in-demand skills: select AIBTM occupations

CIO/IT Director	Systems Analyst	IT Project Manager	Product Manager
Machine Learning	Communication Skills	Communication Skills	Product Management
Communication Skills	Data Science	Project Management	Communication Skills
Software Development	Teamwork / Collaboration	Machine Learning	Teamwork / Collaboration
Artificial Intelligence	Python	Data Science	Data Science
Teamwork / Collaboration	SQL	Teamwork / Collaboration	Machine Learning
SQL	Problem Solving	Artificial Intelligence	Artificial Intelligence
Java	Machine Learning	Planning	Product Development
Software Engineering	Big Data	Big Data	Research
JavaScript	Project Management	Software Development	Planning
Planning	Business Analysis	Budgeting	Project Management
NoSQL	Writing	Writing	Product Sales
Problem Solving	Java	Creativity	Creativity
Creativity	Research	Problem Solving	Software as a Service (SaaS)
Research	Business Process	SQL	Writing
Python	Predictive Models	Data Warehousing	Scrum
Mentoring	Organizational Skills	Research	Problem Solving
Data Science	Oracle	Business Intelligence	Customer Service
Internet of Things (IoT)	Artificial Intelligence	Python	Internet of Things (IoT)
Scrum	Detail-Oriented	Scrum	Product Design
Building Effective Relationships	Software Development	Data Mining	Business Development
Project Management	Planning	Leadership	Software Development
Microsoft Certified Professional Azure	Presentation Skills	Apache Hadoop	Business Case Analysis
Natural Language Processing	Information Systems	Software Engineering	Experiments
Detail-Oriented	Business Administration	Organizational Skills	Detail-Oriented
Budgeting	Systems Analysis	Java	Budgeting

Source: TECHNATION analysis of Burning Glass job posting data

🟨 Core AI skill	⬜ Other technology skill	⬜ Essential/baseline skill
🟡 AI adjacent skill	⬛ Technical skill	

AI Development

AI Development occupations focus on algorithmic design, software development, and implementation. AI software developers/engineers are central to AI research and development. There is more demand for this AI skill set than any other. Demand for software development/engineering professionals is shifting from traditional skills toward AI. Table A-3 portrays the growth of AI development job postings 2015-2018.

Table A-3
AI Development job postings

Job Title	2015	2018	Share of all postings for occupation (2018)
Software Developer / Engineer	336	1,069	5%
Computer Systems Engineer / Architect	30	98	4%
Computer Programmer	13	81	3%
Software QA Engineer / Tester	23	46	1%
Computer Scientist	3	36	34%

Source: TECHNATION analysis of Burning Glass job posting data

Software developer/ engineer is the most in-demand AI occupation of all.

Observations on AI Development skills profiles:

- With 1,069 postings, AI software developer/engineer is the most in-demand AI occupation of all. This occupation is an archetype for the AI field.

- Computer scientist occupations see the lowest demand. However, the breadth and depth of their skills profiles suggest they perform advanced work at the frontiers of deep learning and cognitive computing.

- Quality assurance and testing are critical for machine learning, as it is fundamentally a trial and error process. A top in-demand skill is mastery of Selenium, an open source software testing toolkit.

Table A-4 lists the top 25 in-demand skills, ranked by frequency, for four AI Development occupations.[15]

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15   We have excluded the computer systems engineer/architect profile as it is similar to software developer/engineer.

Table A-4

Top 25 in-demand skills: select AI-development occupations

Computer Scientist	Software Developer / Engineer	Computer Programmer	Software QA Engineer/Tester
Research	Machine Learning	Machine Learning	Quality Assurance and Control
Machine Learning	Software Development	Python	Python
Python	Python	Artificial Intelligence	Communication Skills
C++	Java	Communication Skills	Selenium
Deep Learning	Software Engineering	Teamwork / Collaboration	JavaScript
Artificial Intelligence	Communication Skills	Software Development	Java
TensorFlow	Teamwork / Collaboration	C++	Data Science
Computer Vision	JavaScript	SQL	Teamwork / Collaboration
Software Development	SQL	Problem Solving	Automated Testing
Communication Skills	C++	Data Science	Software Development
Teamwork / Collaboration	Problem Solving	English	Writing
Caffe Deep Learning Framework	Data Science	Organizational Skills	Machine Learning
Neuroscience	Microsoft C#	Java	Troubleshooting
Physics	Artificial Intelligence	Planning	Software Engineering
Distributed Computing	Research	Project Management	Software Quality Assurance
Java	Linux	Research	SQL
Robotics	Big Data	Linux	Problem Solving
Data Visualization	Git	Writing	Planning
Microsoft C#	NoSQL	Data Analysis	Software Testing
Quality Assurance and Control	Writing	Detail-Oriented	Artificial Intelligence
Software Architecture	Scrum	Data Warehousing	Atlassian JIRA
English	Creativity	JavaScript	Linux
Problem Solving	Object-Oriented Analysis and Design (OOAD)	Big Data	Automation Tools
Data Science	Apache Hadoop	Data Management	Relational Databases
Image Processing	Unit Testing	Software Architecture	Regression Testing

Source: TECHNATION analysis of Burning Glass job posting data

▨ Core AI skill	▨ Other technology skill	▨ Essential/baseline skill	
▨ AI adjacent skill	▨ Technical skill		

AI & traditional tech skills: differences and implications

How do AI and non-AI software developer/engineer skill sets compare? The answer is important for two reasons. It highlights how easy or hard it will be to reskill traditional software developers/engineers for AI; and, from a labour market perspective, it provides direction on designating AI software developer/engineer as a new and different occupational category (a key recommendation of this Report). Table A-5 provides a comparison of traditional and AI development/engineering skills.

Table A-5
Top 25 skills: non-AI vs. AI software developer/engineer

Non-AI SW Developer/Engineer	AI Software Developer/Engineer
Software Development	Machine Learning
Communication Skills	Software Development
Java	Python
SQL	Java
Teamwork / Collaboration	Software Engineering
JavaScript	Communication Skills
Problem Solving	Teamwork / Collaboration
Microsoft C#	JavaScript
Software Engineering	SQL
Troubleshooting	C++
.NET	Problem Solving
Writing	Data Science
Planning	Microsoft C#
Creativity	Artificial Intelligence
Project Management	Research
Oracle	Linux
Research	Big Data
Linux	Git
C++	NoSQL
Unit Testing	Writing
Organizational Skills	Scrum
English	Creativity
Extensible Markup Language (XML)	Object-Oriented Analysis & Design
Object-Oriented Analysis & Design	Apache Hadoop
SQL Server	Unit Testing

Legend:
- Core AI skill
- AI adjacent skill
- Technical skill
- Essential/baseline skill

Source: TECHNATION analysis of Burning Glass job posting data

Reskilling for AI will be a challenge for many non-AI software developers/engineers.

Reskilling for AI will be a challenge for many non-AI software developers/engineers. Many of their essential and technical skills are transferable to AI. But they also need to learn new technical skills, many of which, like machine learning and data science, are complex. Also, AI work is more about research and experimentation than pre-design and specification: a very different mindset from traditional programming.

For these reasons and more, **governments and labour market researchers should designate AI software development and engineering as a new and different occupational category.** This will enable employers, planners, career choosers and educators to make informed decisions about skills needs, education and training investments, and labour market transition support.
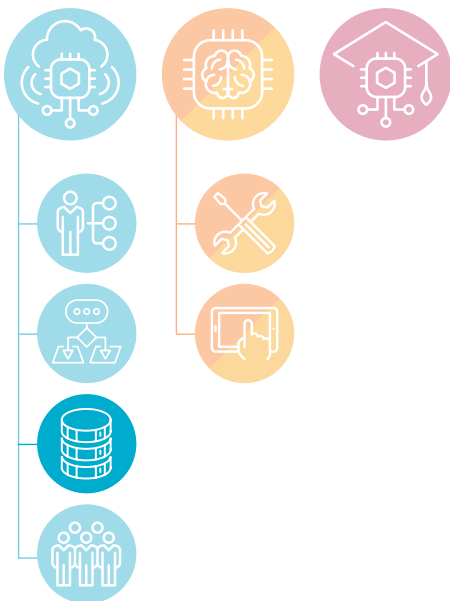
AI Data

As discussed elsewhere in this Report, data science skills are more important for typical AI business applications than software engineering. Our analysis here focuses on four of the six AI Data occupations: data scientist, data/data-mining analyst, data engineer and database architect. These four skill sets (Table A-6), while overlapping, are distinctive and all essential to an effective data science project:[16]

- **Data scientist** is the lead role that pulls together all the relevant data and applies statistical rigour to every step of the process. The data scientist also leads in structuring data for AI algorithms. In small organizations and projects, a data scientist may combine the work of analyst, engineer and/or architect.

- The **data/data-mining analyst** works with business users to identify the data that is pertinent to the goals of the project and identify gaps, inaccuracies and biases.

- A **data engineer** collects and delivers the information, including the architecture that prepares it for processing by AI algorithms.

- A **database architect** (similar to a data engineer) structures the massive volumes of non-standardized data that are often essential to an AI project.

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16   Cassie Kozyrkov, "Top 10 roles in AI and data science." Hackernoon.com, July 26, 2018.

Table A-6

Top 25 in-demand skills: select data management occupations

Data scientist	Data Engineer	Database Architect	Data/Data Mining Analyst
Data Science	Python	Data Architecture	SQL
Python	Big Data	Data Warehousing	Data Science
Machine Learning	Machine Learning	Communication Skills	Data Analysis
SQL	Data Science	Big Data	Communication Skills
Big Data	SQL	SQL	Python
Apache Hadoop	Apache Hadoop	Machine Learning	Teamwork / Collaboration
Research	Java	Apache Hadoop	Machine Learning
Communication Skills	Pipeline (Computing)	Teamwork / Collaboration	SAS
Teamwork / Collaboration	Extraction Transformation and Loading (ETL)	Apache Hive	Tableau
Data Mining	Communication Skills	Python	Research
Predictive Models	Scala	NoSQL	Problem Solving
Data Analysis	Apache Kafka	Java	Predictive Models
Java	Apache Hive	Data Management	Microsoft Excel
SAS	Teamwork / Collaboration	Research	Business Intelligence
R	Relational Databases	Data Science	Creativity
Creativity	Data Warehousing	Extraction Transformation and Loading (ETL)	Data Visualization
Artificial Intelligence	Data Modeling	Apache Kafka	Data Mining
Apache Hive	NoSQL	Business Intelligence	Detail-Oriented
Problem Solving	Data Engineering	Big Data Analytics	Apache Hadoop
Scala	Problem Solving	Software Development	Big Data
Big Data Analytics	Data Transformation	MapReduce	R
Tableau	Linux	PIG	Organizational Skills
Natural Language Processing	Writing	Sqoop	Analytical Skills
Data Visualization	Software Engineering	Data Integration	Writing
Data Transformation	Data Architecture	Data Modeling	Oracle

Source: TECHNATION analysis of Burning Glass job posting data

■ Core AI skill	■ Other technology skill	□ Essential/baseline skill
■ AI adjacent skill	■ Technical skill	

Upskilling a typical traditional data architect to a data science role will not be easy.

Upskilling for data science?

The non-AI occupation that comes closest to data scientist is data architect, a job whose skills profile is dramatically different (Table A-7). Upskilling a typical traditional data architect to a data science role will not be easy. The way forward is to increase public awareness and learning pathways of data science and complementary occupations like AI data engineers, architects and analysts.

Table A-7
Top 25 skills: Non-AI data architect vs. AI data scientist

Non-AI Data architect	AI Data scientist
Communication Skills	Data Science
Teamwork / Collaboration	Python
Data Architecture	Machine Learning
SQL	SQL
Planning	Big Data
Data Modeling	Apache Hadoop
Problem Solving	Research
Research	Communication Skills
Oracle	Teamwork / Collaboration
Data Warehousing	Data Mining
Project Management	Predictive Models
Data Management	Data Analysis
Writing	Java
Extraction Transformation & Loading	SAS
Data Governance	R
Data Quality	Creativity
Building Effective Relationships	Artificial Intelligence
Big Data	Apache Hive
Metadata	Problem Solving
Information Systems	Scala
Customer Service	Big Data Analytics
Microsoft Excel	Tableau
Written Communication	Natural Language Processing
Organizational Skills	Data Visualization
SQL Server	Data Transformation

Source: TECHNATION analysis of Burning Glass job posting data

Legend:
- Core AI skill
- AI adjacent skill
- Technical skill
- Essential/baseline skill

In 2018, 41 per cent of AI postings combined other business or technical skill sets with AI.
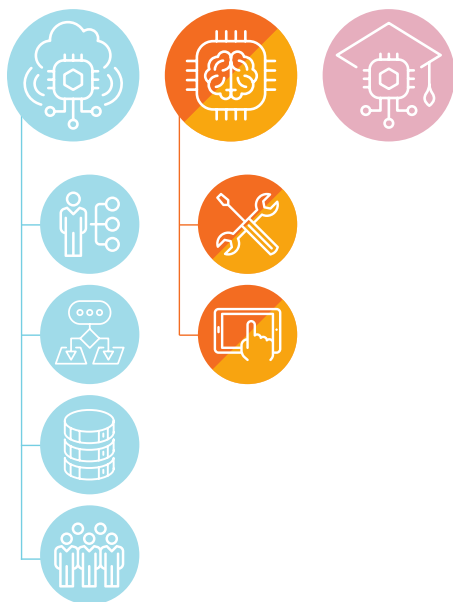
AI Hybrids: an expanding universe

AI Hybrid occupation postings require AI skills for jobs that are not inherently AI-oriented (e.g. data science skills for a medical research job). AI skills are not mere add-ons to traditional occupations (Table A-8). Rather, many jobs are being redefined by machine learning and data science.

AI Hybrid includes two job families:[17]

1. **AI Data-intrinsic hybrids** like business intelligence, financial analysis and marketing analysis (37 occupations in 2018). These jobs entail hands-on work with AI-based analytics, including mid- to advanced-skilled data management and programming.

2. **AI Data-user hybrids** like product management, human resources and retail store management (169 occupations in 2018). These jobs require sufficient AI literacy to knowledgeably lead or function in an AI-enabled environment. They entail basic data management and setting application parameters.

AI Hybrid solutions for data-intrinsic and data-using functions are proliferating in dozens of sectors and professions. Increasingly, employees in leadership, mid-level and front-line jobs need AI and data literacy.

In 2018, 41 per cent of AI postings combined other business or technical skill sets with AI. However, of 2,320 postings for 203 different occupations, 44 per cent are for the top 10 jobs (Table A-8). At the other end of the curve, 129 occupations have five postings or less. Fifty-six occupations have just one posting.

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17   Caveat, our placement of occupations within one or the other hybrid family was based on suppositional assessment of the various titles. It is therefore open to review.

Table A-8

Top 10 AI Hybrid job postings

Job title	2015	2018	Share of job postings for occupation (2018)
Business Intelligence Analyst	80	208	2%
Business/Management Analyst	48	183	1%
Researcher / Research Associate	77	153	6%
Network Engineer / Architect	39	135	4%
Actuary	27	116	18%
Cybersecurity Engineer / Analyst	15	92	2%
Marketing Manager (Data User)	31	82	2%
Financial Analyst	51	62	1%
Market Research Analyst	13	58	4%
Financial Manager (Data User)	26	57	1%
Business Intelligence Architect / Developer	19	50	5%

In Table A-8 marketing manager and financial manager are data-user occupations. All others are data intrinsic.

Source: TECHNATION analysis of Burning Glass job posting data

AI hybrids include a surprising variety of job roles and levels ranging from senior management to front-line workers. Following are some examples, including numbers of AI hybrid postings in 2018.

■ Data-intrinsic hybrids:

Business intelligence analyst	208 postings
Actuary	116 postings
Cybersecurity engineer/analyst	92 postings
Fraud examiner/analyst	31 postings
Logistics/supply-chain analyst	6 postings

■ Data-user hybrids (postings for 169 different occupations):

Marketing manager	82 postings
Human resources manager	30 postings
Retail store manager/supervisor	22 postings
Medical scientist	21 postings
Production plant manager	8 postings
Manufacturing machine operator	7 postings
Chief executive officer	6 postings
Police officer	5 postings
Automotive service technician/mechanic	5 postings

Job postings make it clear that AI skills are not mere add-ons to traditional occupations (Table A-9). Rather, many jobs are being redefined in light of machine learning and data science.

Table A-9
Top 25 in-demand skills: Select Hybrid AI occupations

Business / Management Analyst	Cyber / Information Security Engineer / Analyst	Marketing Manager	Medical Scientist	Human Resources Manager
Communication Skills	Machine Learning	Communication Skills	Research	Planning
Business Analysis	Teamwork / Collaboration	Teamwork / Collaboration	Machine Learning	Predictive Analytics
SQL	Python	Marketing	Communication Skills	Project Management
Microsoft Excel	Information Security	Planning	Python	Research
Data Science	Communication Skills	Problem Solving	Data Science	HR Transformation
Teamwork / Collaboration	Data Science	Predictive Models	Teamwork / Collaboration	Building Effective Relationships
Problem Solving	Software Development	Project Management	Writing	Listening
Microsoft Powerpoint	Research	Data Science	Data Analysis	Meeting Deadlines
Project Management	Java	Creativity	Creativity	Robotics
Planning	Artificial Intelligence	Digital Marketing	Predictive Models	Human Resource Management Industry Knowledge
Research	Big Data	SAS	Biology	Teamwork / Collaboration
Economics	Apache Hadoop	SQL	Deep Learning	Creativity
Business Process	Information Systems	Key Performance Indicators (KPIs)	High-Performance Computing	Problem Solving
Decision Making	C++	Organizational Skills	C++	Professional Services Marketing
Microsoft Office	Network Security	Product Management	Artificial Intelligence	Information Technology Industry Knowledge
Predictive Models	Planning	Marketing Analytics	Robotics	Machine Learning
SAS	Threat Intelligence and Analysis	Microsoft Excel	Software Development	Leadership
Data Analysis	Threat Analysis	Detail-Oriented	Java	Artificial Intelligence
Artificial Intelligence	Big Data Analytics	Research	Statistical Analysis	Critical Thinking
Big Data	Analytical Skills	Market Strategy	Statistics	Written Communication
Tableau	Microsoft Active Directory	Artificial Intelligence	English	Communication Skills
Python	Security Operations	Risk Management	Organizational Skills	SAP
Machine Learning	Linux	Direct Marketing	Problem Solving	Budgeting
Business Intelligence	Splunk	Budgeting	Data Collection	Candidate Sourcing
Budgeting	Domain Name System (DNS)	Microsoft Powerpoint	Data Visualization	Global Talent Acquisition

Source: TECHNATION analysis of Burning Glass job posting data

Legend:
- 🟨 Core AI skill
- 🟡 AI adjacent skill
- ⬜ Other technology skill
- ⬜ Technical skill
- ⬜ Essential/baseline skill

Appendix B:
AI case studies

How does software design for AI translate into an output or business strategy?

Rio Tinto:
A mining industry AI leader

With 47,000 employees in 35 countries across six continents, Rio Tinto is one of the world's biggest mining companies. Nearly a third of its workforce is in Canada, where the company engages in aluminum smelting, hydro-power generation, and exploring and mining for diamonds, iron ore, titanium and other minerals.

In an industry often seen as high-tech averse, Rio Tinto is a leader. In Australia, the company is pioneering driverless trucks on production sites, the world's first driverless railway system (the largest robot in existence), and a highly automated "Mine of the Future."

In Canada, Rio Tinto is working on AI applications in several areas. Over a recent 12-month period, the company filled about a dozen data specialist, scientist and engineering roles as part of an initiative to improve the aluminum production process. Candidate requirements included a combination of AI/data science fundamentals, advanced technical skills, and familiarity with cloud-based AI services like Amazon Web Services and Microsoft Azure.

In August 2019, Rio Tinto Canada advertised for a lead in human resource data science and two human resource data scientists to help develop enterprise-wide HR analytics capacity. Rio Tinto Canada also offers data science upskilling to motivated employees with suitable skills profiles. Indigenous communities and diversity are taken into consideration when hiring, and the company is prepared to train recruits in AI.

AI talent challenges described by Rio Tinto include talent sourcing:

- High competition in the market.

- Rarity of required skills and profiles.

- High salary expectations due to the rarity of these profiles.

- Lack of knowledge and practical application of all or part of the software/tools commonly used. (Even basic transferable skills, let alone custom builds).

- Lack of AI project experience (implementation, leadership, stakeholder management). For example, how does software design for AI translate into an output or business strategy? Such knowledge can be worth billions of dollars in eventual value to the company.

Rio Tinto Canada executives highlight the necessity of a pipeline of quality data scientists is necessary. They offered these recommendations regarding Canada's AI workforce:

- Develop applied AI programs in regional universities close to Rio Tinto operations.

- Make it easier for qualified foreign AI workers to obtain work permits. Global skills are not easy to find. Relocation can take many months and be painful.

- Focus graduate programs/curricula on innovation with more programs focused specifically on AI. It's important to not only learn these skills but also how to adapt them for industry. Often the best candidates end up in the US, at big technology firms or in academia.

> **Cloud-based services produce "a hundred unique innovations per week. If we just commercialize that for our clients, we are ahead of the game"**

Deloitte:
AI consulting leverages the cloud

Deloitte Canada is a member of the global Deloitte professional services network. Industry analysts rank its consulting division as the world's largest. Omnia Group is its 600-plus-person AI practice.

With over 550 job postings in 2018, Deloitte is the only professional services firm among Canada's top five AI job posters.[18] Omnia's software development group produces industry-specific AI solutions to complement the firm's client services. Offerings address contract management, physician workflow, infrastructure risk management, cybersecurity and digital-media risk monitoring, among other areas.

Omnia's client sectors include financial services, technology/media/ telecommunications, public sector, health care, energy and resources. In addition to software product development, its services include defining AI strategy, custom algorithmic design, data preparation, usability design and AI/machine-learning application development. Omnia relies heavily on cloud-based AI capabilities from Amazon Web Services, Google Cloud and Microsoft Azure. It deploys in-house algorithm design only when necessary. Cloud-based services produce "a hundred unique innovations per week. If we just commercialize that for our clients, we are ahead of the game," notes Deloitte Managing Partner Steve McCaughey. Omnia's AI-based client projects include:

- Predictive and micro-market analysis for retail online chat and customer loyalty;

- Social media sentiment analytics;

- Psychographic matching of clients to bank wealth management advisors; and

- Technology that identifies event triggers for mergers and acquisitions.

The company hires people with strong technical fundamentals and relevant technology experience. The typical education baseline for software developers is a bachelor's degree in computer science or engineering. Applied data scientists require an advanced degree in data science and/or AI.

Deloitte reports difficulty finding suitable AI candidates at all levels of experience, especially cloud-based software engineers, applied data

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18   Per the Burning Glass research cited in this report.

scientists and DevOps professionals.[19] Hardest to find are candidates with three to five years of experience. Undergraduate courses and AI programs remain well below demand. Promising students are recruited in third year for post-graduation hiring, with compensation packages as high as $130,000.

Deloitte believes graduates of nearly all programs need basic AI understanding. The firm works with colleges and polytechnics, which it finds responsive to the need for practical machine learning and data science skills. The firm also recruits international candidates, including some who can't obtain US entry permits.

19   DevOps is a set of practices that combines software development (Dev) and information-technology operations (Ops) which aims to shorten the systems development life cycle and provide continuous delivery with high software quality. (Wikipedia, November 30, 2019).

> **"You need to be literate in AI to function in the modern world. It's become an essential skill."**

Dawson College: AI for everyone

Montreal's Dawson College is the first Canadian post-secondary institution to declare that every graduate should achieve a level of AI literacy. The plan, which follows a Quebec government initiative on digital literacy,[20] has broad industry support. The first classroom steps happened in the 2019/20 academic year.

The Dawson initiative could have ripple effects across the education system and the broader economy. With 11,000 students, Dawson is Quebec's largest Collège d'Enseignement Général et Professionnel (CEGEP). A two-year CEGEP diploma is mandatory for all Quebec-based university entrants. Dawson, like other colleges, also offers three-year professional diplomas in fields such as diagnostic imaging, industrial design and nursing.

The intent of the AI initiative is to equip all graduates with discipline-relevant AI concepts, appreciation of societal issues such as AI ethics, and occupational skills for AI-enabled work. Many will have hands-on AI technical experience.

Defining the role for AI across all programs is in progress. In the meantime, Dawson is bringing basic AI to all students in the short-term by including AI in general education courses, mandatory for all CEGEP students.

Dawson is also implementing other immediate changes, such as expanded AI in computer science education and AI-related content in science-related programs. For example, diagnostic imaging technologists are learning to use AI tools that are better than humans at timing an image exposure. AI skills are being to the humanities and other fields. No discipline will be untouched—not even cinema, where AI models now classify scripts for target audiences.

AI tools are also being introduced to improve student success and access to services, and to improve classroom pedagogy.

Fully integrating AI into structured multiyear programs requires time. Every program is formally reviewed about every 10 years. Changes require Quebec government approval. This begins during the 2019/20 academic year with the Diagnostic Imaging Technician program and will continue over the coming decade.

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20   See Gouvernement du Québec, Éducation et enseignement supérieur, Plan d'action numérique en éducation et en enseignement supérieur.

Dawson's faculty-led AI change leadership infrastructure has four elements:

1. A multidisciplinary, cross-functional executive team.

2. A network of faculty communities that generates ideas, shares learnings, and builds AI teaching capacity. Participation includes annual rotations to bring new ideas and expose more people to the process.

3. Mandated faculty Fellows who receive time off teaching to innovate and develop curriculum and pedagogy.

4. An AI advisory board of about 30 leaders from the AI sector, other employers and educational institutions.

Ray Bourgeois, Dean of Academic Initiatives, says the AI strategy enjoys enthusiastic support from faculty and staff. Like any major cultural and organizational change, he says, implementing the strategy will take effort, time, and awareness-building. For example, a few individuals see AI through a Hollywood lens, wherein *Terminator*-like robots displace humans.

Bourgeois advises other institutions to consider an AI-everywhere strategy. "Focus on what you want your graduates to know, rather than specific programs," he says. "This is like literacy. You need to be literate in AI to function in the modern world. It's become an essential skill."

Appendix C:
Burning Glass descriptions
for select technology occupations

These are generic occupation descriptions. We defined a job posting for one of these (and other) occupations as AI-specific when it includes a requirement for at least one AI skill. The list of AI skills was developed jointly by TECHNATION and Burning Glass.

Computer Programmer. Writes code, or instructions that a computer can follow, to create software programs. Follows program designs created by software developers and assists with software program design work. Updates and expands programs, tests for errors and fix errors. Uses different computer languages as needed to write programs.

Computer Scientist. Conducts research and studies complex problems in computing. Develops computer algorithms that provide the foundation for advances in technology. May study computer hardware architecture, robotics or software, and collaborate with electrical engineers and other computer professionals.

Computer Systems Engineer/Architect. Creates computer and data communication networks for companies and organizations. Plans and designs layout for a network; determines the hardware needed and placement of computers, servers, cables and routers; determines data storage and system capacity, speed and software needed for a system.

Data / Data Mining Analyst. Develops computer programs to analyze large customer information databases for companies and organizations. Analyzes data to identify patterns and provide information relevant to a particular business, industry or field; analysis may be used for marketing, or to detect fraud in financial transactions, or for research. Develops computer programs to protect confidential customer information.

Data Engineer. Designs, builds and manages the information or big data infrastructure. Develops the architecture that helps analyze and process data in the way the organization needs it. Makes sure those systems are performing smoothly.

Data Scientist. Utilizes skills and experience to systematically answer questions using data to provide actionable recommendations. Commonly utilizes advanced statistical analysis and machine learning techniques. Common responsibilities also include data cleaning and data management.

Data Warehousing Specialist. Designs, builds and maintains computer systems that store large amounts of data for companies and organizations. Implements systems for processing or retrieving data as needed to analyze activity or company operations; addresses security and privacy requirements for data.

Database Administrator. Uses software to store and organize data, such as an organization's records or financial information. Ensures that users can easily access the information they need, and that data are protected from unauthorized access.

Database Architect. Builds integrated data systems for a company or organization. Creates structures needed for different types of information processed, integrates structures into a system that is reliable and secure, sets system standards, and provides help with troubleshooting and access to data.

Software Developer / Engineer. Designs or improves computer software. Oversees the entire software development process. Analyzes customer or user needs, designs program, writes code or instructs computer programmers, tests design, and documents programs. May assist with upgrades or maintenance. May specialize in the design of computer applications or computer systems.

Software Quality Assurance Engineer / Tester. Designs and runs in-depth diagnostic tests to evaluate software and check for problems before new products are marketed. Pilots software and applies tests to check for errors and glitches.

Appendix D:
Methodology and limitations

This report draws on three sources:

1. Extensive literature review, including primary and secondary sources.

2. In-depth interviews and discussions with leading industry practitioners, including suppliers and users of AI-related services. These discussions enabled us to validate and refine our models and hypotheses (such as the primacy of machine learning), as well as the Burning Glass job posting data results.

3. TECHNATION analysis of exclusive, commissioned job posting data from Burning Glass Technologies, a Boston-based research firm. The data is scraped from most of Canada's leading online job boards as well as employer online job notices.

Burning Glass job posting data

Burning Glass "real-time jobs data" are compiled by scanning the internet using bots that seek out job postings on job boards, corporate websites, and other places where job ads are posted. The firm's software extracts topline information about each job such as title, occupation, employer, and location, and then uses natural-language technology to read each job description to identify specific occupations, skills, and qualifications that employers are seeking. Burning Glass can track several elements, such as the specific skills of individual jobs, that aren't available in traditional labour market data sets.

Burning Glass uses machine learning to resolve duplication and map the contents of postings to its taxonomies of occupation groups, specific occupations, skills clusters and individual skills. The taxonomies are based on categories defined by O*Net, a widely used reference sponsored by the US Department of Labor.

How we define AI occupations

Occupations that require AI skills entail researching, designing, building, developing and implementing AI-based systems. To qualify as an AI position for this Report, an advertised job posting must include at least one AI skill per a list developed jointly by TECHNATION and Burning Glass. Employer requirements for AI skills appear in postings for hundreds of different

occupations. They appear among postings for information technology focused jobs like software engineering and data science. They also appear among postings for non-IT jobs like financial analyst, actuary, retail manager and medical researcher.

Limitations

The data provided in this report is regarding employer job postings: it does not measure actual employment.

The Report data uses 2015 as a baseline year and 2018 as the most recent growth year. The data should be interpreted as a snapshot of two points in time. It is not a projection of future growth. The report does not capture recent events, such as an uptake of machine learning in Canada's oil sands reported in late 2019.[21]

Because some job postings are for replacement positions, the data does not quantify net job growth. However, three-year growth in demand for various AI occupations is typically well over 100 per cent. It's likely that only a small proportion of these postings are for replacement jobs.

The data does not quantify actual numeric demand. This is for three main reasons:

- Many AI jobs are filled without being posted online. This includes direct hires and internal transfers.

- Some job posting sites are not accessible to Burning Glass.

- French language postings are not included in Burning Glass job posting data.

For these reasons, the high demand velocity described in **this report** *understates* **numeric demand for AI professionals in Canada.**

All demand data in this report is with reference to the Burning Glass job posting data described herein. Readers should treat precise numbers as trend estimates, which are typically underestimates. Growth percentages are likely close to actual, depending on sample size.

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21   Geoffrey Morgan, "Cenovus joins Big Oil's push into Big Data with Amazon and IBM deals", *Financial Post*, November 26, 2019.