THE DIGITAL SKILLS GAP BETWEEN NEW GRADUATES FROM ENGINEERING AND COMPUTER SCIENCE AND INDUSTRY EXPECTATIONS

Highlights from the Literature Review (Author Dana Prymak)

The purpose of this document is to share findings and create interest in future conversation

A literature review was undertaken to examine research publications and industry sources throughout North America and Europe to inform the Building Capacity Through Competency Development Project: a partnership between the University of Victoria and Canada’s Digital Technology Supercluster, funded by the Ministry of Advanced Education and Skills Training. The review looked at the: relationship between digital skills, digital competency, and digital literacy; the definition of a digital skills gap; the main drivers of the digital skills gap; and digital technology competency frameworks. The highlights from the review are provided below.

Emerging technology is reshaping the future of work. Almost all industries rely on technology and demand for digital skills has been increasing more swiftly than supply.

Key Findings

1. The digital skills gap is impacted by complex connections between the rapid rate of change, new drivers and mega trends.
   - Digital skills are defined “as a range of abilities to use digital devices, communication applications, and networks to access and manage information.”
   - Digital skills are constantly evolving, hence, influencing the digital skills gap.
   - As the pace of change accelerates, new drivers and megatrends behind the skills gap transform more and more aspects of work.
   - The interconnectedness between megatrends such as changing workforce demographics, underrepresentation of women and other groups, automation, digitalization, climate, geography, business model innovation, and emerging technologies are contributing to digital skill gaps.

2. New graduates need both hard skills and soft skills to succeed and remaining relevant in this fluid environment can only be met by lifelong learning. Soft skills are now more commonly referred to as professional skills.
   - Soft skills include reading comprehension, critical thinking, writing, social awareness, complex problem solving, decision making, service orientation, coordination with others.
   - Hard skills include coding languages, data analytics, cloud computing, IoT, mechatronics, performance metrics, project management, digital security, and security management.
   - Many experts refer to this phenomenon (needing both hard and soft skills) as a hybrid or a T-shaped talent.
• The T-shape indicates both depth of expertise in one or more technical disciplines (vertical), combined with the breadth (horizontal) to understand, innovate and work across an organization with the ability to influence others, collaborate across disciplines, and develop creative solutions to complex business problems.3,4,6,7

3. While there are many different competency frameworks, there are also many similarities between the frameworks,8,9,10,11

• Comprehend and engage the digital environment
• Effectively create and consume digital information
• Communicate effectively
• Collaborate with diverse stakeholders
• Innovate rapidly/be an agile thinker
• Think critically/solve problems
• Maintain cybersecurity.
A. Relationship Between Digital Skills, Digital Competency, and Digital Literacy

Digital skills allow an individual “the possibility of exploring, expressing, criticizing, and understanding the flow of thoughts between individuals and collaborative groups in rapidly evolving technical environments.” Digital skills are the foundation of digital competency. In addition to understanding of how to use technology, digital competency “involves understanding of privacy and security, role of Information and Communications Technology (ICT) in society, and complex cognitive skills and ethical knowledge, given the evolving nature of technologies.” Competence is seen as a way to achieve a degree of literacy. Being digitally-literate means being able to “use information and communication technologies to find, evaluate, create, and communicate information, requiring both cognitive and technical skills.”

The absence of a common definition seems to impact policies and programs which are developed around the terminology.

B. What is a digital skills gap?

Digital skills gap is the difference between supply and demand for candidates with technical proficiency in the labour market.

Among the most common skills implied by digital skills are:

- Business Process Management (BPM)
- Robotic process automation
• cloud computing
• emerging technology
• agile program management
• cybersecurity
• effective internal and external communications.

Digital skills are continually evolving.\textsuperscript{20,21} The adoption of smart and connected technologies, such as the Internet of Things (IoT), will continuously reshape the future of work.\textsuperscript{22}

The digital transformations present opportunities for productivity and efficiencies which will require employees to evolve and learn new skills as technologies and digital tools change throughout their career. To thrive in the future, new graduates need to embrace the concept of lifelong learning – enhance skills through massive open learning courses (MOOCs) and stackable micro credentials while employed.\textsuperscript{23}

National Occupancy Classification system (NOC) - a system that classifies occupations in the Canadian labour market does not define what skills and competencies are required for the job.\textsuperscript{24} The system is considered to be limited in the context of digital and technology-based occupations – some of the most in-demand jobs are not included and emerging occupations are often placed under categories that do not fully represent the essence of the occupation.\textsuperscript{24}

C. What are the main drivers of the digital skills gap?

CEOs and academics world-wide agree that automation and digitalization are among the main driving forces behind the skills gap.\textsuperscript{4, 8,9,25,26,27,28} Some believed that the driving forces behind the skills gap were more complex. The interconnectedness between megatrends such as climate, business model innovation, cybersecurity, demographic change, underrepresented populations, and emerging technologies are contributing to skill gaps.\textsuperscript{2}

Since digital transformation is becoming the core enabler of future success, companies will continue to search for new efficiencies, productivity-enhancing technologies and talent that can work with such technologies. For example, the Deloitte polls showed that 76% of employers invested in connected technologies to address margin challenges, and 24% invested in drones and robotics to improve workers’ productivity and safety.\textsuperscript{28}

Small and medium-sized enterprises often have limited professional development funds and in-house resources to respond to fast-changing digital technologies which further contributes to the gap.\textsuperscript{29}

It is important to acknowledge that the repercussions of COVID-19 pandemic and associated system disruptions revealed deep disparities in people’s access to education
and barriers to employment which has further fuelled the skill gaps conversation. Research on underrepresented groups is forthcoming as part of this project.

C.1. In-demand Hard Skills

The ability to adapt to rapidly changing environments and roles is believed to be a key to career success. Employees will be expected to learn new hard skills as well as soft skills. Taxonomies for digital skills are changing as fast as the technology around us.

The Information and Communications Technology Council identified eight key digital occupations for the future and their critical hard skills. The majority of skills were related to knowledge of specific coding languages such as Python, SQL, Java, C/C++, Tableau, PHP.

The Stack Overflow Developer Survey 2020 of 65,000 software developers from 186 countries found the Rust, Typescript, and Python programming languages to be the most popular languages. The survey showed that 75% of respondents learned a new technology at least every few months or once a year. In addition to programming languages, other drivers for new digital skills within the UK construction and infrastructure sector was Building Information Modelling.

Some other skills that are believed to help narrow the digital skills gap were:

- statistical and augmented analytics
- cloud computing (cloud service level agreements (SLA))
- the cornerstones of IoT
- data analytics
- mechatronics (mechanical, electrical, computer, and controls engineering)
- performance metrics (project performance)
- remote, agile project, and program management
- competitive vendor management (request for proposals, projects)
- digital security and security management.

Big Data Management was the most sought-after skill by employers and the key to making important business decisions. Big Data Management consists of several steps, in addition to knowledge of programming skills (e.g., data warehousing, computational frameworks, data mining, etc.). While graduates might have some of the skills required to perform these processes, they needed to learn how to make connections between these steps on their own to succeed in the labour market.
As artificial intelligence, machine learning, and automation are playing increasingly large roles in workplaces, several studies noted a lack of advancement in cybersecurity skills gap.\textsuperscript{41,42} To keep up with the pace of technological progress, the training mechanisms in place must be nimble enough to adapt to these changing requirements.\textsuperscript{30} Industry leaders suggested paid apprenticeship programs and micro credentials, as opposed to traditional degree programs, as a direct pathway to employment.\textsuperscript{43,44,45}

Some industries (IT, health care and cybersecurity) in the U.S. started to adapt the concept of apprenticeship programs to create a workforce that can achieve in-demand competencies and meet the necessary demands of the fast-paced, tech-driven future of work.\textsuperscript{44}

A strong learning and mentoring culture are at the core of the apprenticeship program success.\textsuperscript{44}

\textbf{C.2. Emerging trends}

It is crucial to pay attention to emerging trends in the fields that are just gaining momentum and are expected to grow in the future because some of the future skills do not yet exist.

\textbf{Artificial intelligence and robotics are highly anticipated technologies.}

Others that can shape the future of work include:\textsuperscript{46}

\begin{itemize}
  \item autonomous vehicles
  \item distributed ledger
  \item additive manufacturing
  \item Internet of Things
  \item and immersive technologies.
\end{itemize}
Many of these changes will necessitate upskilling and/or reskilling.\textsuperscript{47} As a result of autonomous vehicle development and implantation, software engineers’ occupation will see an increased demand.\textsuperscript{47} Automotive advanced driver system engineers, automated vehicle research engineers, and autonomous vehicle trainers are among jobs that will become more popular as Canada enters autonomous vehicles market.\textsuperscript{47}

**Climate change and demand for sustainable technologies** is expected to increase and will require innovative approaches.\textsuperscript{48,49}

One report found that for engineering construction to succeed in industry decarbonization by 2050, the industry required skilled individuals in CO2 pipeline monitoring, production of synthetic fuels and repurposing of salt caverns for hydrogen shortage.\textsuperscript{6}

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\textit{“Not a skills gap, but a learning curve”}

Tyler Farmer and Mairead Matthews, Information and Communications Technology Council\textsuperscript{8}

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One of the studies conducted by the Information and Communications Technology Council found that Canadian employers do not experience challenges accessing skilled talent.\textsuperscript{50} Since credentials on immersive technologies are relatively new and date back to 2017, the majority of currently employed are self-taught.\textsuperscript{50}

Generally, the employers indicated they tended to look for someone who can learn new tools and applications as they are released.\textsuperscript{50} Whereas self-learning is likely to remain a trend, employers may expect more traditional post-secondary credentials such as bachelor’s degrees, diplomas, and certificates.

**C.3. In-demand Soft Skills**

\textit{“In highly technical roles, strong digital skills are necessary - but not at the expense of strong soft skills.”}

Viet Vu, Creig Lamb, Rob Willoughby, Brookfield Institute\textsuperscript{24}

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The BC Labour Market Outlook 2019 has identified the top five skills and competencies that will be necessary for future jobs.\textsuperscript{25,51}

**Top 5 Skills**
- Active listening
- Speaking
- Reading comprehension
- Critical thinking

**Top 5 Competencies**
- Social perceptiveness
- Judgement and decision making
- Complex problem solving
- Coordination with other people
No digital or tech-oriented skills were part of the list – a partial explanation could be that the forecasting models are built on historical data which in aggregate reporting might not signal emerging digital trends. The outdated methodology of NOC system might also impact the forecasting model behaviors. However, omitting digital skills might not be coincidental.

Critical thinking and communication abilities were at the core of the ability to understand user needs, functional requirements, and expectations, and to match technological solutions to the clients' needs.32

The nature of the digital skills gap may not be as digital as it might be interpreted.52 In order to understand digital culture and digital working culture, learning leaders need to invest in a T-shaped or hybrid talent.3,4,5

The T-shape symbolizes the fact that the technical knowledge must exist before other elements; the horizontal part of the T can be added and explored throughout the career.3

As the technological transformations continue, some expected that by 2030 digital skills gap might reverse the mentoring relationship where younger employees might be asked to mentor older colleagues on topics such as technology and change management.53
The hybrid trend is not new to the labour market.

The Survey on Employment and Skills 2020 showed that when Canadians think about skills that are needed to succeed in the workplace, they spoke about technical know-how knowledge of a specific subject related to the job, followed by communication skills. Based on similar survey findings and job posting analysis, the Brookfield Institute for Innovation and Entrepreneurship drew readers’ attention to four prominent trends for hybrid roles:

- Combination of baseline workforce digital skills and strong interpersonal, problem-solving, and project management skills
- Proficiency in a variety of digitally intensive tools and strong interpersonal, problem-solving, and project management skills
- Knowledge of digitally intensive and augmented digital tools along with creativity, communication, design, and arts
- Advanced data skills as the work stream becomes more computerized.

D. Competency Frameworks

“A competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilizing psychosocial resources (including skills and attitudes) in a particular context.”

OECD
This definition captures the evolving nature of complexities and the need for competency models and frameworks to address megatrends and drivers that may be barriers to preparing more digitally skilled workers.\textsuperscript{2,55}

The search for examples of digital competence frameworks revealed an extensive work done by the industry and academia. Frameworks identified were centered on seven critical abilities:\textsuperscript{56}

- Comprehend and engage the digital environment
- Effectively create and consume digital information
- Communicate effectively
- Collaborate with diverse stakeholders
- Innovate rapidly/be an agile thinker
- Think critically/solve problems
- Maintain cybersecurity

**Sample frameworks**

D.1. **Royal Bank of Canada (RBC)**

*The Coming Skills Revolution: Humans Wanted. How Canadian Youth Can Thrive in the Age of Disruption* \textsuperscript{8}

The RBC report divided the Canadian economy into six clusters based on skills: Solvers, Providers, Facilitators, Technicians, Crafters, and Doers.

Engineers and computer scientists fall under Solvers (people who innovate and find solutions to intractable problems).

Forty-five percent of working Canadians are expected to become solvers by 2021.

The report stated that to be prepared for the future jobs, young Canadians need to be able to move between the clusters by taking short bootcamp courses.

D. 2. **The Brookfield Institute for Innovation and Entrepreneurship**

*I, Human: Digital and Soft Skills in a New Economy* \textsuperscript{9}

Like the RBC report, the Brookfield Institute has grouped competencies into clusters that they expected to be in-demand in the future. The report suggested that in the future employers will be looking for a blend of digital and non-digital skills.

Since the NOC system does not offer an up-to-date classification of digital skills and occupations, the authors created a new system of assessing occupations and what level of digital literacy and knowledge are required for jobs.

The system placed digital skills “on a continuum based on their relative digital intensity.”\textsuperscript{9}
General workforce digital skills (dark blue) – skills included in the most in-demand occupations across the Canadian economy – the ability to use web-based project software, Microsoft Office, and accounting software.

Data skills (pink) – focused on data collection and analysis, data modelling, Big Data, business intelligence as well as knowledge of specific tools such as Apache Hadoop, Tableau, and R.

System infrastructure skills (light blue) – consisted of digital infrastructure management ranging from setting up and managing cloud computing services to more general IT support. Proficiency in VMware, Windows Server, system administration and hardware and software installation skills were most commonly mentioned in this group.

Software/Product Development skills (yellow) – skills needed to generate new digital web- and software-based products: Java, Python, software development, software engineering, and web development – highest demand for hybrid occupations (e.g., AI project manager, AI sales manager).
A meta-analysis of research about 21st-century skills revealed skills that fall under foundational literacies, competencies, and character qualities (see figure 8):

- **Foundational literacies** - skills that are the base upon which students need to build more advanced and equally important competencies and character qualities.

- **Competencies** are essential to the 21st-century workforce, where being able to critically evaluate and convey knowledge, or work well with a team, has become the norm.

- **Character qualities** are crucial to discovering new concepts and ideas, having constructive interactions with diverse others, and demonstrating resilience in the face of obstacles.
Digital literacy and software literacy served as a foundation to the framework for the US Department of Defense.

The four competencies (yellow) referred to how engineers create digital processes to understand a phenomenon of interest.
Additional competencies were identified for each level and are listed on the right and left of the main blocks. Depending on the role, an employee would require certain competencies; however, no role will require all competencies.

The four competency areas of Data Engineering, Modelling, Decision Making, and Engineering Methods are essential to digital artifacts lifecycle. Each of these areas was based on five competency types:

- **Manage/Lead**: understanding of the overall context, strategic long-term, and tactical short-term technological support
- **Architect**: Transforming objectives to systems and structures for long-term support
- **Develop**: Designing, implementing, and providing necessary validation and verification
- **Support**: Creating and supporting the digital environment, tools, and libraries to provide the maximum value
- **Use**: Use the tools and artifacts to provide maximum value.

**Conclusion**

A review of literature in relation to *Identifying the Digital Skills Gap Between New Graduates from Engineering and Computer Science and Industry Expectations* has revealed many interesting points that would benefit from further discussion between post-secondary institutes and industry leaders.

Various drivers and megatrends are affecting the digital skills gap in the workforce and need to be considered when attempting to close the gap. Artificial intelligence, digitalization, automation, and climate change, lead the list of trends. Driven by these trends and the unprecedented pace of change in digital technology advancement, companies will be looking for employees who are quick learners, effective communicators, and agile critical thinkers while being fluent in technology.

Employees who have technological knowledge and professional skills are commonly referred to as hybrid or T-shaped professionals. As technological advances become more embedded in every aspect of day-to-day lives, there will be a greater emphasis on the importance of understanding digital technology. Thus, the demand for t-shaped employees is expected to increase.

While there is currently no general agreement between different competency and literacy frameworks, there is an increasing acceptance of the need to focus on hard and soft/professional skills. Hard and soft skills are no longer considered as two distinct groups but are integrated at every level of development.

The Building Capacity Through Competency Development Project will use this literature review as a basis for exploring the digital skills gap and competency framework with
industry partners through survey and focus group activities and creating capacity for co-operative learning opportunities.

This Project endeavors to explore how post-secondary institutions and industry can collaborate; to close the gap so new graduates are better prepared to meet industry needs; to help industry better identify their needs; to support employees in remaining relevant and to encourage the development of diverse T-shaped workforce.

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