Current and Emerging Practices in Engineering Education

Final Consultant Report

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Executive Summary

Engineering regulators have asked Engineers Canada to undertake a strategic priority to *Investigate and validate the purpose and scope of accreditation*. The goal of this priority is to understand the perspectives of stakeholders, confirm requirements, and propose a path forward that will meet the needs of regulators while keeping current with the realities of engineering education.

In support of this strategic priority, the following report provides a synthesis of current and emergent practices in engineering education within Canada and internationally. The report was guided by discussions of the Engineering Education Task Force, and a full-day *Engineering Education in Canada Workshop* that was held on January 17, 2022 with regulators and educators and co-hosted by Engineers Canada and Engineering Deans Canada.

To identify current engineering education trends in Canada, an environmental scan was completed of engineering education research and practices using the proceedings from 2020 and 2021 Canadian Engineering Education Association - Association canadienne de l'éducation en génie (CEEA-ACEG) conferences. Twenty-seven topics were identified in the scan, which ultimately led to the discovery of three main trends occurring in engineering education in Canada, and 8 representative topics:

I. **Flexible and Assessed Pathways:**
   1. Realizing new pathways into engineering;
   2. Competency-based assessment; and
   3. Micro-credentials

II. **Open and Inclusive Culture**
   4. Equity, diversity, and inclusion (EDI);
   5. Indigenization and decolonization; and
   6. Well-being and whole student

III. **Student-Centered Engineering Education:**
   7. Integrating behavioural and technical skills;
   8. Experiential learning; and
   9. Project/Problem-Based Learning, as well as gamified education and flipped delivery

In addition to this scan, eleven artifacts that focused on the future of engineering education were reviewed. These included reports, papers, and statements by institutions or engineering dean's associations written between 2018 and 2022. These artifacts largely echoed the findings of the CEEA-ACEG scan, with an emphasis on problem and project-based learning to address real-world challenges, integration of empathy, the inclusion of industry-connected experiences, diverse teams, and interdisciplinary experiences. Online and remote teaching were also noted as likely to continue once the current COVID-19 pandemic is over. Additional topics arose in the future of engineering education reports that were not discussed as prominently in the CEEA-ACEG scan, including:

1) flexibility and modularity of engineering programs organized into blocks of learning;
2) personalized education;
3) oral exams;
4) shifts in the sources of global engineering education leadership; and
5) the continued emergence of new specializations.

The questions that arise from these emergent practices for consideration by the Engineering Education Task Force, Steering Committee and other stakeholders following this consultant report are:

1) Where are these identified current and emergent engineering education practices most likely to stretch the current accreditation system's design or be restricted by its current design?
2) What are the implications and considerations? and
3) What is occurring in the engineering education ecosystem that provides further context for these trends and considerations for the strategic priority?

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Introduction

Purpose

The purpose of this report is to understand the current landscape of engineering education within Canada and identify international trends that indicate the future of engineering education, which will inform future decisions about the Canadian engineering accreditation system.

This report provides a synthesized scan of current and emergent practices in engineering education with accompanying descriptions and examples of those practices to inform the Engineering Education Task Force's discussions and reporting as part of Engineers Canada's strategic priority to *Investigate and Validate the Purpose and Scope of Accreditation*.

Context of Engineering Education at the Time of this Report

Engineering Education has and will continue to change in many ways [1]. We have gone from using slide rules to graphing calculators to solve mathematical design problems, to now using machine learning and other artificial intelligence (AI)-based applications to inform our designs [2]. The use and expansion of technology within engineering education and within the profession has been profound and has led to increased consideration of the important behavioural skills and qualities that engineers bring to the table, such as empathy and active listening, and critical thinking [2, 3].

Engineering educational programs are now faced with educating students to be engineers in a global economy and a changing climate that is increasingly uncertain, interconnected, and multifaceted [3, 4], wherein these behavioural skills such as teamwork are of equal importance to the technical engineering knowledge. With targeted efforts to increase diversity within engineering programs, student demographics are shifting, both accelerating change within engineering education and crystallizing the need for it.

TEXTBOX (ITALICS TO INDICATE, NOT ITALICS IN TEXTBOX): In their paper entitled Stuck in 1955, Engineering Education Needs a Revolution [5], Sorby and colleagues describe the shift from practical hands-on work to teaching theory that occurred after the 1955 Grinter Report, and how this approach has remained largely unchanged since. They argue for a 'sea change' in engineering education that will address the needs of today's 'digital, diverse, global, and rapidly changing society.' The situation that Sorby et al. described is echoed in the Canadian engineering education research landscape [1, 6, 7], and the need for change in engineering education is also broadly recognized within the Canadian engineering education research community, with many lamenting the lack of evidence-based pedagogical practices, the inertia and difficulty of change within academia, and the slow pace of cultural-change required to advance equity in our programs [1, 8, 9, 10]. Though there are many educators who are 'tinkering *around the edges,' the 'basic structure of the curriculum remains unchanged even though our students can now find information on their phones that might have taken us hours to track down in the library' [5, para. 1].*

Underpinning several of the emergent practices for engineering curriculum design are the needs to address the looming skills gap [3], address shortages in the labour market, and adapt to the changing nature of employment, according to American Society of Mechanical Engineers and Australian Council of Engineering Dean reports [11-13]. Alongside these macro-shifts, the importance of individual career paths and 'lifelong, self-directed learning,' and the desire for students to be able to document and discuss their own skills and achievements are growing. 'Learning how to learn and recognising that rapidly changing, business, economic and social environments mean that graduates will need to learn and relearn throughout their careers' [14, p. 49].

An example to showcase the scale of cultural shift within an engineering program as to how and what students learn that is emerging in response to societal shifts: the related ability to self-document skills 'will grow increasingly important as the ‘gig’ economy, fueled by freelance and contract workers, continues to grow as large companies refrain from hiring full-time employees' [13, para. 23]. Practices related to self-directed learning have the potential to transform a program, increasing the flexibility of how and when students learn, and shifting the role of students from passive participants to co-creators of their learning journey. The Charles Sturt University (CSU) Civil Systems Engineering Program offers a case study example [9]. Their program was designed to be 'underpinned by self-directed learning: …[and] takes a student-centered, experiential approach that emphasizes self-directed learning. Students are confronted with a series of on-campus challenges and work-based problems and are expected to identify, master and apply the knowledge and skills necessary to tackle them, as well as reflect upon their learning. Students are also encouraged to direct and manage their own learning goals' [9, p. 24]. In this example, coursework, class time activities, assessments and the role of faculty and students have all shifted from traditional didactic approaches.

This report outlines substantial changes in engineering education. The landscape of engineering education is now a composite with notable shifts in some programs, some courses and some years, especially first years. There has been growth in educational technology [15] and in micro-engagements (e.g., embedded readiness quizzes and check-ins with peers). However, there is still concern about the extent of change, as some authors have noted: though the need for change is broadly recognized in literature, engineering classes remain content-focused and delivery largely lecture-based [16], including after the COVID-19 pandemic [17]. A North American study of over 2000 STEM classrooms echoed this, showing that the vast majority of instruction is lecture-based, with fewer than 20% of engineering classrooms incorporating student-centered instructional styles [17, 18]. However, the almost universal shift from in person courses to remote delivery gave many engineering faculty members experience with educational technologies and development opportunities that they may not otherwise have had, which may catalyze a change in the teaching practices of some educators [17]. The questions arise as to whether there is a critical mass across all levels of education in the changes, and the implications of the changes for accreditation.

With growing calls for change from governments, educators, and students [1, 5, 17, 18], structures and policies are shifting to remove barriers to curricular changes and scalability [11, 12], opening the possibility for a ‘period of rapid and fundamental change’ [9, p. 40] within the engineering education sector. This consultant report outlines specific ways in which engineering educators are designing engineering education for the future.

Methodology

With the goal of identifying current realities and emerging trends within engineering education in Canada, several sources were used to identify general trends and those which warranted deepened discussion.

Engineering Education Task Force

Engineering educators including current and former Deans, current faculty, and regulator volunteers who are also faculty, volunteered and were selected for the Engineering Education Task Force (Task force). The Task force mandate is to set the scope for this report in collaboration with regulators and educators, to provide guidance to Engineers Canada staff and project consultants on the development of the Task force report, to review the final draft report and presentation and provide feedback to finalize them. Members include Michael Isaacson (chair), Christopher Yip, Claude Laguë, Malcolm Reeves, Paul Amyotte, and Suzanne Kresta. From November 2021 to January 2022, the Task force met to develop the workshop and to debrief (described next). They also met to discuss feedback on this this report in March 2022.

Engineering Education in Canada Workshop

Engineers Canada and Engineering Deans Canada co-hosted a full-day *Engineering Education in Canada Workshop* on January 17th, 2022 with educators and regulators from across the country. Sheryl Sorby, Immediate Past President of the American Society for Engineering Education presented a keynote talk titled *Disruptions in Engineering Education for Diversity, Equity, and Inclusion*, and two panels were held: *What innovations are shaping engineering Education?* and *What Would EDI Look Like in Engineering Education?* A pre-reading package and discussion group questions for the workshop were informed by Task Force discussions. A summary report on the workshop was provided to participants. A list of participants is included in Appendix 1 of this report. Key themes from the day are noted in Appendix 2a. Topics Across Sources.

Scan of CEEA-ACEG Proceedings

To provide a thorough overview of current engineering education trends in Canada, the abstracts, keywords, and conclusions of all 2020 and 2021 Canadian Engineering Education Association (CEEA-ACEG) proceedings were reviewed. There were 85 conference papers in 2020 and 98 in 2021; the proceeding titles, links to abstracts, and topics found are shown in Excel file Appendix 2 of this report, sheet 2b. The papers were thematically coded to identify what each paper was about as well as any additional educational trends that were noted. To ensure a sufficient sampling, whereby the rate of new topics slows, both the 2020 proceedings and the 2021 proceedings were included [19].

Review of International Future of Engineering Education Reports, Papers, and Institutional Statements

11 internationally-sourced education reports, papers, and statements by institutions, and publications by engineering associations from 2018 to 2022 that focused specifically on the future of engineering education were reviewed and analyzed to see if further topics emerged outside of those identified in the CEEA-ACEG scan. The full results of this coding process are shown in Appendix 2c. Nearly all CEEA-ACEG-identified topics were confirmed through these reports and six additional themes were noted that are described in this report:

1) modularity and flexibility;
2) personalized education;
3) self-documenting skills;
4) oral exams;
5) the continued emergence of new specializations; and
6) a global shift in who is leading innovation in engineering education.

Focused Descriptions of Specific Topics

From the above scans, three trends were selected to be described in-depth in this report. All three trends were present in the CEEA-ACEG scan and future of engineering education reports and were prevalent at the Engineering Education in Canada Workshop. All three trends have implications for engineering education structures, overall program curriculum design, policies, cultures, and students' paths through programs. Topics were selected using an operational sampling approach, where specific examples are selected for their ability to deepen (operationalize) the description of each trend [19]. The three trends and representative topics are:

I. **Flexible and Assessed Pathways**

1. Realizing Flexible Entry and Bridging Pathways for Students
2. Competency-Based Assessment
3. Micro-credentials

II. **Open and Inclusive Culture**

4. Equity, Diversity, and Inclusion
5. Indigenization
6. Well-being and Whole Student

III. Student-Centered Engagement with Complex Problems

7. Integrating Behavioural and Technical skills
8. Experiential learning
9. Project/Problem-Based Learning

Current and Emerging Trends in Engineering Education

Identified Topic areas

Twenty-seven current and emerging practices (topics) in engineering education were identified in the CEEA-ACEG 2020 and 2021 proceedings, as shown in Appendix 1. Table 1 summarizes the specific topics that were found and associated trends.

Table 1: Identified Current and Emerging Practices (CEEA-ACEG proceedings)

Trend	Specific Current and Emerging Practices (Topics)
Methods of and support for evidence-enhanced teaching	• Faculty and teaching assistant support • Educational technologies • Online teaching • Asynchronous learning
Increasing the flexibility of engineering education	• Pathways into engineering programs such as one-year programs or technical program agreements with engineering degree programs • Bridging programs for students entering engineering direct or indirectly from high school; competency-based assessment • Micro-credentials that are indicators of specific skill development or demonstration
Cultural shifts in engineering education	• Equity, diversity, and inclusion • Indigenization and Indigenous knowledge • Student wellness, and the whole student • Development of students' empathy and bias awareness
Student-centered and active learning	• Active learning involving pedagogical practices that engage students cognitively, affectively, and socially • Flipped delivery where the didactic learning occurs outside of class and before students attend class for active discussion, problem-solving or hands-on learning • Gamification where games are used to engage students • Co-op and internship placements in industry • Experiential learning with real-world problems, contexts, or simulations • Design courses • Problem and project-based learning
Development of new skills	• Entrepreneurship • Digital literacy • Self-reflection and awareness • Integrating behavioural skills of lifelong learning, ethics, and teamwork (including in relation to complex problems)
Expansion of partnerships	• Including students as partners and co-creators of curriculum • Community or industry partnerships

	• International partnerships including the development of international connections through teaching international students, collaborating with international partners, and students being sent to and received from abroad

As noted, three trends were selected to be described in-depth in the trend sections of this report.

Highlights From International Future of Engineering Education Reports

The future of engineering education review included 11 reports, publications, and statements by institutions from 2018 to 2022 including educational institutions such as MIT, the American Society of Mechanical Engineers, and the multi-year Engineering 2035 Project by the Australian Council of Engineering Deans. The reports are listed in Appendix 2c. These reports described the future of engineering education based on over 170 interviews [9], projections to 2050 [11], and case studies [14], as well as sessions with educators and industry leaders [11 - 13]. These artifacts largely echoed the findings of the CEEA-ACEG scan, with an emphasis on problem and project-based learning to address real-world challenges, integration of empathy, the inclusion of industry-connected experiences, diverse teams, and interdisciplinary experiences. Reassuringly, most themes that were identified also aligned with the CEEA-ACEG themes (see Appendix 2d). Five additional themes were identified in the reports that were reviewed with implications for current and emerging engineering education.

a) Modularity

Considerable shifts in curriculum structure are visible in the emergence of modularity, where topics and skills are grouped into subsets of time and instruction that are smaller than traditional 12 to 16 week courses. Modularity offers flexibility to students' paths and more active engagement of students in planning their program of study where opportunities to repeat, choose sequences, and choose between modules exist. Modularity and flexibility also address the challenge of the growing applications and areas of focus in engineering: 'Engineering is entering so many areas that engineering education will require more flexible progra[ms], so as to better respond to the needs of society and the wishes of students. This can be achieved through modular approaches for the implementation of engineering programmes' [20, p. 1820].

b) Personalization and Self-assessment

Personalized education reframes "universities as places that support both the personal and professional development of students, helping them in their path to fulfill their dreams. Accordingly, in a student-centred university, students should also responsibly decide and take a more [active] part in their curricular planning,' [20, p. 1820] as they do in the emergent practice of SLICCs (Student-Led, Individually-Created Courses). Within engineering specifically, students can follow many paths beyond the 'fundamental core,' such as service learning, research, entrepreneurship, and '[students need to be allowed] to explore these things, [so that they can] choose a pathway that suits their talents and interests' [9, p.43]. Personalization requires a shift in content, activities, and assessments within a program, and provides a potential role for micro-credentials, which offer students both the ability to pick and choose relevant content and documents their achievements. This shift would generate more paths for students, not only to follow, but create for themselves.

c) Oral Examinations

Assessment within engineering programs is changing, including with the acceptance of oral examinations. Faculty members at the University of California, San Diego began using oral exams to maintain academic integrity, 'but they quickly discovered advantages over traditional written tests. Students learned to articulate their analytical work clearly and formed better bonds with their instructors' [21, para 4.4]. These advantages suggest the potential for continued use within academic programs.

d) Emergence of New Specializations

The growth of new specializations is a current and expanding challenge and opportunity within engineering education. The final report [12] of the Australian Council of Engineering Dean's (ACED) two-year future of engineering project entitled Engineering 2035 noted that 'engineering programs have typically been structured within a discipline base. However, in recent years, new degree programs have emerged that focus on specialisations in emerging and converging disciplines such as aerospace systems, biomedical, environmental, mechatronics, resources, and renewable energy engineering' [12, p. 12]. The emergence of new specializations comes with new curricula that may extend further into interdisciplinary collaborations and courses outside engineering with potential implications for engineering credits counts.

e) Shift in Global Leadership

Lastly, Dr. Ruth Graham's *The global state of the art in engineering education* report for MIT stated the impact of this global shift being that 'things are happening in places you have never even heard of, all over the world. Doing the same old thing is suddenly not going to be good enough' [9, p.40]. Overall, the 'emergence of a new generation of [institutional] leaders with the capacity to deliver student-centered curricula at scale,' proving that it is possible to develop new approaches to engineering education anywhere; and 'a tilting of the global axis of engineering education leadership so it is less focused on U.S. and northern European institutions' [9, p. 39].

Across the multiple current and emerging trends in engineering education, the ACED report identified perceived barriers to curriculum and pedagogy change including 'the cost of scaling up for large cohorts, especially in practice-based education; limited access to industry partners and lack of availability of work placements; limited availability of qualified teaching staff with significant industrial practice; programs that target specific student cohorts rather than looking to a diverse student intake; resistance to change; organisational structures and disciplinary silos; and accreditation of programs that challenge traditional models' [12, p. 12]. The scoping report that was a part of the same Engineering 2035 project, noted that there is limited assessment of program impact (e.g., quality of graduates, value-add to students during studies, and capacity to deliver world-class education) in the engineering education sector [14]. Program impact assessment appears to be limited in the Canadian literature as well.

Trend 1. Flexible and Assessed Pathways

Engineering, along with higher education in general, is being pushed towards greater flexibility for students [14, 19]. Three identified trends were selected to reflect relevant changes with potential impact on engineering educational programs' structures, timelines, and assessments.

For all of these practices, good constructive alignment across learning outcomes, activities, and assessments are key to the successful deepening of learning [22], and enhancement of teaching and learning quality [22].

1. Realizing Flexible Entry and Bridging Pathways for Students

As part of a commitment to increasing access to engineering programs for marginalized or underrepresented students, engineering schools are looking for new pathways for learning [20]. Student pathways into and through engineering education have expanded in many ways, including transfers between institutions, articulation agreements between engineering technology and engineering degree programs, and the elimination of mathematics and/or physics prerequisites into programs [14], such as the elimination of the high school calculus requirement in the University of Saskatchewan's engineering admission requirements. Their admission page, as of March 2022, states: "Calculus 30 has been removed as an admission requirement for the Bachelor of Science in Engineering program, effective for admissions to the 2019-2020 academic year. If you are taking calculus now or have already completed it, that's great! If it works to your advantage, it can still be used in an admission average calculation and the experience you have gained will be very valuable to your first year in engineering. Removing high school calculus as an admission requirement is a way for us to reduce barriers to entry into engineering, and to grow and diversify enrolment in this in-demand and impactful field."

Engineering articulation agreements aim to formalize pathways between engineering technology programs and engineering degree programs. These formalized pathways, often referred to as transfer programs, provide students with a clearly articulated 'block' of transfer credits. There are many individually negotiated transfer agreements across Canada that are specific to individual diploma/degree programs, for example:

- An articulation agreement between Saskatchewan Polytechnic School of Mining, Energy, and Manufacturing and the University of Saskatchewan (U of S) College of Engineering allows students to transfer with a set block of course credits, applicable to the Geological Engineering degree program at the U of S.
- The University of Calgary developed a 2+2 program in Energy Engineering, which allows a student who has completed a technology diploma (typically in mechanical, chemical, petroleum, or power engineering technology) to transfer into the Schulich School of Engineering to complete their final 2 years a B.Sc. in Energy Engineering.

Additionally, there are efforts to establish province-wide efficiencies in British Columbia, Ontario, Alberta, and Quebec:

- The British Columbia Council on Admission and Transfer commissioned a report entitled First-year Core Engineering Curriculum for the BC Post-secondary Sector, which investigated the feasibility of developing a core engineering curriculum to be used across the six major research universities in BC, allowing students to begin their studies at one and transfer out afterward.
- The Ontario Council on Articulation and Transfer has been investigating the feasibility of a multi-institutional transfer pathway between engineering technology and engineering degree programs. Their report entitled Bidirectional Transfer Pathway for Ontario's Engineering and Technology Programs outlines a pilot program which is still being considered.
- Transfer Alberta outlines six institutions with 'official transfer programs in Engineering' where students, after one year, can transfer to the University of Alberta or the University of Calgary. Transfer Alberta also lists established pathways via an engineering technologist program into an engineering degree.
- Pathways from CEGEP to engineering degree programs in Quebec (e.g., Polytechnique Montréal's admissions)

Notably, the formalized pathways provided by transfer agreements offer predictable blocks of specified courses with set course outcomes. These agreements allow students to bypass one to two years of an engineering program without the engineering programs having oversight over instructors, access to assessments, or the ability to direct students' paths.

2. Competency-Based Assessment

Competency-based assessment (CBA) is an established practice within the engineering profession, as multiple regulators in Canada have moved towards CBA to assess engineering work experience for applicants for engineering licensure [24]. One benefit of this form of assessment is that it is 'more objective, transparent and consistent and increases the confidence of all who participate in the process including applicants, validators, employers and assessors' [24, para. 2.1].

Higher education and engineering education programs across Canada are showing increasing interest in and application of CBA [25]. At the course level, CBA "highlighted to students how they were performing, allowing them to focus on weaknesses, and allowing the instructional team to provide additional assistance as needed" [25, p. 4]. At both the course and program-level, the curricular shift to competency-based assessments can provide opportunities for students to reassess core competencies or to repeat assessments, which requires all students to successfully demonstrate all key competencies to pass [25, 27]. Typically, students are given a simple task that is easy to assess and must master this initial task before moving on to more advanced work. The intention of this is to demonstrate that a student has understood or achieved an acceptable level of competence with a specific skill before moving on, which in turn helps ensure that when a student passes a course, they have mastered the core concepts [26, 27]. Competency-based assessment has many benefits in engineering-specific contexts, including the potential for 'validating performance against accreditation criteria' [27, p. 2].

Existing initial examples of competency-based assessment in Canadian engineering educational programs:

- Implementing a Competency-based Assessment in a First Year Engineering Design Course at Queens University
- A Competency Based, Student-centered Assessment Model for Engineering Design at the University of Calgary.

In an example of investing in a program approach to CBA for first-year students, the University of Saskatchewan recently 'RE-Engineered' their first year to incorporate modular courses and CBA:

- Design of a Completely New First Year Engineering Program at the University of Saskatchewan

In addition to CBA, there is a growing body of literature on specific assessment methods for engineering education competencies, or learning outcomes, that can be used within CBA or as one-off assessments in courses. Competency measures summarized in a 2019 systematic review [28] of 99 studies showed that the development of valid and reliable competency measures requires: defining each competency and its subcomponents, performing confirmatory and exploratory factor analyses, and using student reflections on their ability with each competency to validate that the measure was accurate. Although only a few CBA assessments and CBA engineering programs have been designed so far, there is growing interest and application of CBA both by educators and regulators in engineering [29]. Notably, applying CBA to authentic activities within a course was considered substantially more complex than for applying CBA to individual tests [25].

3. Micro-credentials

Digital badges, or micro-credentials, are portable digital icons meant to confirm that a learner has attained a specific and discrete skill or competency. Proof of learner competency, including requirements met to achieve the micro-credential, information about the issuer, and other relevant information is embedded as metadata in the credential itself. Across Ontario, eCampus Ontario defines a micro-credential as a 'certification of assessed learning associated with a specific and relevant skill or competency [that] enable[s] rapid retraining and augment[s] traditional education through pathways into regular postsecondary programming' [30, para. 5]. While some micro-credentials are offered based on participation for a specified time or tasks completed, best practice indicates that badges should mostly rely on outcomes-based assessment. Micro-credentials can allow programs or institutions to provide recognition for prior learning or indicate demonstrated ability with specific skills or outcomes.

There has been significant institutional interest in micro-credentialing in Canada, with major government funding announcements, including in BC, Alberta, and Ontario [31] in the past two years. However, the concept is still relatively new. A University of British Columbia Okanagan research team noted in their paper, *Badging for Accreditation: Electronic Credentialing in the Undergraduate*

Curriculum, that 'badging seems viable as a strategy for meeting accreditation requirements, particularly in areas that are historically challenging to instruct, assess, and report: for example, life-long learning and professionalism. In the short term, then, badging can function as a highly visible and very flexible supplementary curricular intervention, and in the longer term it has potential to be embedded within curricula' [32, p. 3]. Internationally, a New Zealand Tertiary Education Commission's commissioned report identified how micro-credentials could be used to improve the uptake of engineering education in New Zealand [33].

Engineering programs across Canada are beginning to offer co-curricular micro-credentials to their students, for example:

- McMaster University Faculty of Engineering – MacChangers Program
- University of British Columbia Okanagan School of Engineering – Skills in Industrial Automation - Programmable Logic Controllers
- University of Calgary Schulich School of Engineering – Foundations of Software Engineering Program Completion Badge

In addition to engineering program investment in micro-credentialing, several high-profile companies, including IBM, Microsoft, and Google are starting to offer their own micro-credentials. They are partnering with the same badging/micro-credentialing platforms that educational institutions use to offer professional development and training to current or potential employees.

Beyond pathways, CBA, and micro-credentials described above, flexibility for students can be provided through teaching innovations such as online and blended learning [1], new technological teaching tools such as simulations and virtual laboratories (e.g., PhET interactive simulations for science and math), and virtual reality [14].

Trend 2. Open and Inclusive Culture

'The current generation of students are not content to address social justice and equity issues in only their private lives… to engage students, we need to demonstrate the relevance of engineering curricula to their concerns' [5, para. 5]. Cultural shifts within engineering education programs are emerging that reflect growing societal engagement in equity, diversity, and inclusion (EDI); Indigenization, decolonization, and reconciliation; and an awareness of the importance of sustainable development. Behavioural skill development, including empathy and awareness of bias, is paramount in these endeavors.

There is a need for greater diversity in engineering as an ethical imperative, and to address both the existing bias in engineering design [5, 34], and how current engineering curricula insufficiently serve a diverse student body [14]. The changes to improve equity are structural, according to a National Centre for Student Equity in Higher Education research report by Naylor and Milsud [35]: 'Structural barriers may range from exclusionary discourse in the classroom, to inflexible enrolment and assessment policies, to privileging particular communication styles. Structural inequality is the converse of traditional deficit and ‘cultural resources’ models of student support: rather than asking how students can acquire missing skills needed to leverage success within an institution, it asks what institutions can do to make themselves more or less inclusive and navigable for all students (and even staff and the wider community). In shifting from a model where the deficit is in the individual student to a model where the deficits (structural barriers) are in the system, the responsibility for change is therefore shifted from students, or from areas associated with outreach and academic literacy programs … to all actors within the institution' (35, p. 1]. This report [35], which is focused broadly on Australian higher education systems outlines three types of structural inequalities of the educational systems:

- 'Vertical inequalities' in access to higher education;
- 'Horizontal inequalities' in opportunities to enter 'highly selective fields of study';
- 'Internal inequalities' where 'particular characteristics or backgrounds may also be disadvantaged within the institution itself; for example, by being less likely to complete their degree’ [35, pp. 8 - 9]. Internal inequalities and differences in outcomes may occur due to two broad categories of challenges: 'personal or relatively external factors that may impact on ability to study (for example, financial constraints, caring responsibilities, mental well-being); and difficulties navigating the administrative and support units in the institution, or institutional norms that do not support these students' [35, p. 9].

All three types of inequalities are visible in the descriptions of system-level barriers to equity, diversity, and inclusion (EDI), reconciliation and Indigenization which are discussed in more detail in the next section. Steps to addressing structural internal inequalities encompass administrative processes, communication, and environment; adjusting curriculum design and administration including assessment policies; improving physical environments; and ensuring access to appropriate support services [35].

4. Equity, Diversity, and Inclusion

In brief, *diversity* increases the range of people in the space; *inclusion* is how they are valued and have a sense of belonging in that space; and *equity* is the removal of systemic barriers faced by individuals and groups historically and presently marginalized by social and administrative structures and norms.

Engineers Canada describes the definition and rationale for diversity as:

> *'...engaging the best minds of the profession, which includes women, Indigenous peoples and internationally educated professionals. Increased diversity and inclusivity within the engineering workforce provides significant benefits to Canadians by delivering a solution to overcoming skills shortages, increasing innovation capacity and providing a greater return on human resource investment. Engineers Canada strongly believes that diversity and inclusion within engineering will ensure the sustainability of the profession and its ability to understand the public it serves'* [36, para. 1]

Engineers and Geoscientists British Columbia's 2021 [*Professional Practice Guidelines – Equity, Diversity, and Inclusion*] [37] offers the following definitions for diversity, equity, inclusion and the related concept of marginalization as listed in Table 2.

Table 2: Definitions of EDI

Term	Definition
Diversity	"The variety of unique dimensions, qualities, and characteristics we each possess. Some of these elements are physical (such as age, sex, and physical abilities), others are socially constructed (such as race and gender), and others are a result of our circumstances and experiences (such as religion, education level, and nationality). Diversity is the inclusion of different types of people—such as people of different genders, sexual orientations, races, cultures, religions, physical, or mental ability—in a group or a Firm." [37, p. vi]
Equity	Determines the specific and unique needs of each group that has been historically, systemically, and persistently marginalized, with a view to what needs to be done to create inclusive environments without barriers to participation and advancement. Equity is sometimes used interchangeably with the concept of equality; however, their meanings are different. In particular, equality is focused on providing everyone with the same amount or types of resources without a view to whether these resources address their specific barriers. [37, p. vii]
Inclusion	Having a sense of belonging and/or being valued for one's unique contributions, as well as those held in common with others. Inclusion is an environment or culture that strives for Equity, and values and respects Diversity." [37, p. vi]
Marginalization	"The intentional or unintentional exclusion of a group of people based on stereotypes, Unconscious Bias, misinformation, and/or superiority. [37, p. viii]

Engineers and Geoscientists British Columbia also provides specific terms and concept descriptions "pertaining to specific Equity-Seeking persons (i.e., women, Indigenous Peoples, people with disability, people of colour, newcomers, 2SLGBTQ+ people" on their Equity, Diversity, and Inclusion webpage [37, p. vi].

Internationally, 'It was also recognized that increasing student numbers would inevitably bring a greater diversity in student demographics and background. Although it was noted by many that "we cannot continue to cater to the same type of students, we need to attract the students that would not normally think of engineering," it was also suggested that a more diverse student body was not well served by current engineering curricula' [9, p. 36].

It is widely agreed that 30% is the tipping point where the participation of a minority group, in our case female-identifying students or engineers, is normalized, and culture begins to change [38, 39, 40]. For decades, engineering schools in Canada have aimed to increase the number of women in their programs, with results remaining largely stagnant at the undergraduate level [38, 39, 40], with the proportion of female-identifying students in engineering programs vacillating between 20-25%, according to Stats Canada. There are some notable exceptions, such as UBC reaching 32% in the 2018/2019 year and the U of T reaching 40.2% of first year students identifying as female, but there is no province in Canada where the female-identifying engineering enrolment is above 30%, according to Engineers Canada's Canadian Engineers for Tomorrow. The proportion of full-time female-identifying and male-identifying engineering undergraduate students in Canada from 2010-2020, according to Statistics Canada Post-secondary enrolment report (Table 37-10-0011-01) is displayed in Figure 1. Details of the downloaded report and figure creation are found in Appendix 3. In the same timeframe, the proportion of total female-identifying faculty in engineering programs has risen slowly to approximately 17% as of 2019.

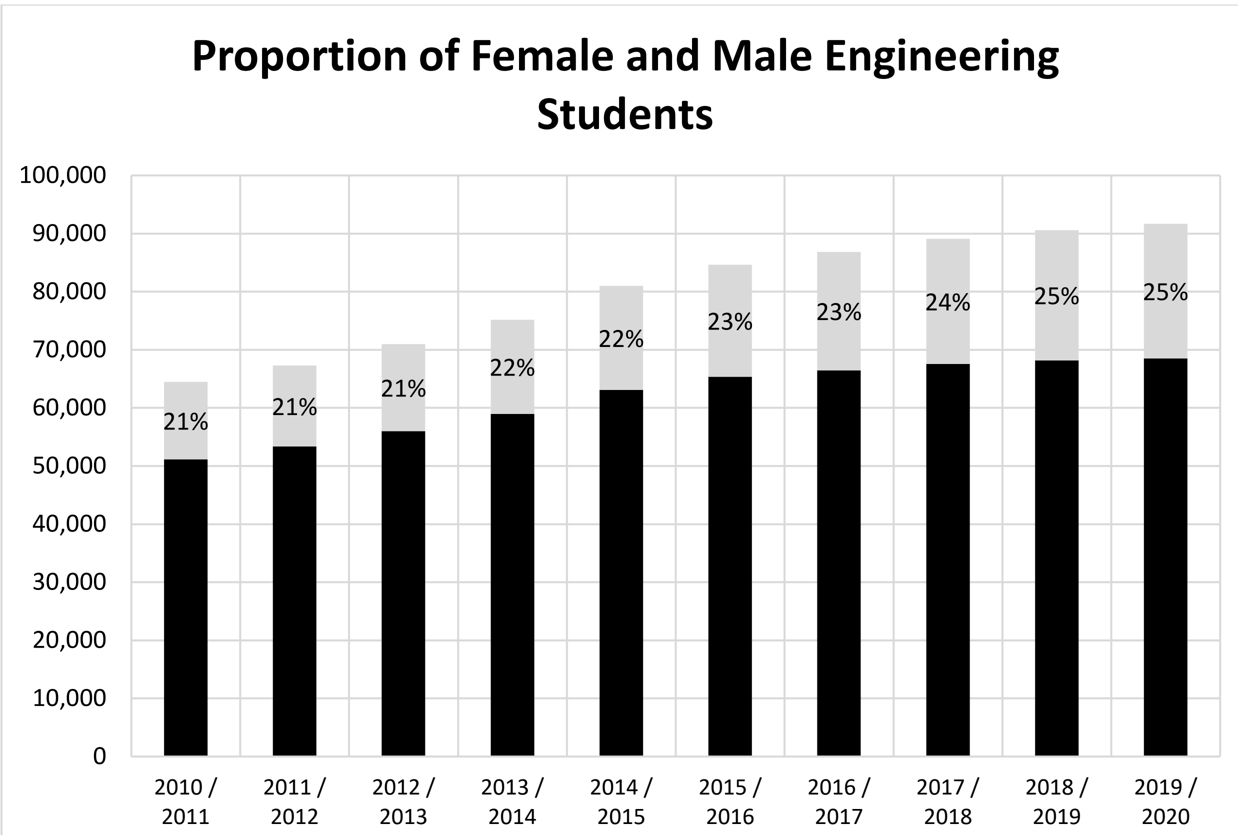

Figure 1 Proportion of full-time female to male students in Canadian undergraduate engineering degree programs 2010-2020

The numbers in Canada and Australia are starkly different than in Europe, where over 40% of engineers are female-identifying, and Iran, where the percentage of female-identifying engineering students has reached nearly 70% in the past. The 2018 *Global state of the art of engineering education* report further documents how Singapore University of Technology and Design has '[relatively high] Female participation for a technology-focused university: women represent 40% of the undergraduate population overall and 30% of those based in engineering-focused disciplines' [9, p. 66], and Delft University of Technology, the oldest and largest of Netherland's three technology-specialist universities, has ‘17 bachelor programs … home to a student population of around 11,400, of which 26% are female’ [9, p. 141].

Many engineering schools continue to have specific recruitment strategies and outreach programs targeted to women in engineering, as well as undergraduate initiatives such as the Women in Action initiative at Queens University or the Women in Engineering - Career Launch Experience program at Concordia University. These programs have increased the number of female students, but parity is not yet achieved [41], and significant resources are still being invested to identify which interventions are successful, including through the SINC Project, which is a part of the larger Engendering Success in STEM collaboration, supported by Engineers Canada.

While there is a particular focus on women in engineering, there is also a recognized need for diverse perspectives from multiple equity-seeking groups including: differently-abled, culturally diverse, LGBTQ2SA+, Indigenous, and racialized students. A multi-year Engineering 2035 project by the Australian Council of Engineering Deans (ACED) aimed to find 'significant drivers of change in professional engineering roles and anticipate the impacts of these changes on the expectations of future graduates of professional engineering programs towards the year 2035,' which involved five individual reports. Their scoping report noted that: '… It is desirable that diversification also includes greater gender, ethnic, and cognitive diversity in the engineering student and graduate cohorts' [14, p. 3]. Greater diversity in the engineering profession is seen as a necessary step towards both greater sustainability for the profession and better design [5]. To that end, EDI concepts are being embedded within design courses, to ensure 'that students can … understand human capabilities and limitations, so their designs are better suited to a wide range of users' [34, p. 1].

Addressing EDI requires programmatic, structural and cultural changes. While engineering schools have identified the benefits of and need for greater diversity in their programs, 'there is a growing need to critically look at the embedded culture of engineering and how this presents a barrier to diversity' [38, p. 1]. 'To ensure that we are attracting and retaining a diverse pool of learners to our programs, we need to examine what we are teaching and how we are teaching it' [5, para. 3]. In order for underrepresented students to feel welcome, equity and inclusion practices will need to adapt [42], and structural barriers will need to be removed [35]. Removing structural barriers to EDI requires significant change; for example: investment in EDI-awareness and capacity building of staff and faculty within engineering to champion change, increasing availability of asynchronous offerings to students who may need to work while they attend university or who have families or other responsibilities, and creating more flexible pathways into engineering programs [35]. Embedding EDI into an engineering program’s systems, structures and culture involves institutional policies and practices, supportive leadership at senior and departmental levels, and allocation of resources to support the success of these initiatives [43].

Initiatives like Indigenous and Black Engineering and Technology (IBET) PhD Project, Ontario Network of Women in Engineering (ONWiE), EngiQueers, and advancing Indigenous people in STEM through AISES (American Indian Science and Engineering Society) chapters in Canada directly address these challenges and build a matrix of support for all engineers and engineering students. There is also action underway to identify specific changes within Canadian institutions. For example, a recent campus-wide faculty survey at a Canadian university highlighted several issues related to EDI, including: career progression challenges for racialized faculty, lack of diversity on hiring committees, silencing and retaliation for raising identity or race issues, and adverse impact on work. They identified a need for genuine engagement on these issues and outlined recommendations including equity audits, reporting of disaggregated intersectional EDI data, and 'supporting the proposed Indigenous and Black faculty hiring program' [44, p. 14].

5. Indigenization

Addressing truth and reconciliation is necessary in Canadian engineering programs as an ethical imperative [45], and as an expectation of professional engineers. Provincial regulators such as EGBC and APEGS have specific reports and statements regarding truth and reconciliation steps. 'Engineers interface with, and directly impact Indigenous communities through infrastructure and economic development projects. So, building student capacity for intercultural understanding, empathy, and mutual respect is critical in our profession contributing to Reconciliation' [46, para. 2]. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) [47] raises expectations for engineers and engineering programs understanding of Indigenous rights. For example, UNDRIP articles such as article 29 'Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources' [47, p. 21], furthers requirements for free, prior, and informed consent that changes the way engineering conduct consultations with many communities.

The Indigenization of engineering education is best described as existing on a spectrum [48]. One end of the spectrum allows the academy to 'maintain most of its existing structures' and on the other end, the 'university is fundamentally transformed by deep engagement with Indigenous peoples' [48, p. 1]. In their paper entitled *Indigenizing engineering education in Canada: critically considered*, Seniuk Cicek et al. summarize these terms as follows:

- 'Indigenous Inclusion [includes] attempts to increase the number of Indigenous faculty, staff, and students in engineering institutions. This includes outreach attempts to create pathways to postsecondary programs and professional careers, and camps for children/students.
- Reconciliation Indigenization includes Indigenous Knowledges to educate faculty, staff, and students via courses and training.
- Decolonial Indigenization, described as decentering hierarchical Western Eurocentric postsecondary structures and 'empower[ing] Indigenous communities to regain educational sovereignty'… This looks like Knowledge Keepers and Elders in postsecondary spaces, exclusive Indigenous spaces, and Indigenous Knowledges centered in curricula' [10, p. 8].

Truth and Reconciliation and Indigenization cannot be subsumed within EDI policies and initiatives. In addition to broader awareness and capacity-building encouraged by institutional and governing bodies, Indigenization must involve Indigenous leadership and result in policy changes that advance the inclusion of Indigenous knowledge in curricula. The work of decolonizing engineering education will require a critical assessment of engineering accreditation policies [10].

Engineering programs are working to support Indigenous students and advance Indigenization in many of the ways described above, including:

- Indigenous Initiatives at the University of Saskatchewan include an Indigenous student work-integrated learning experience, a 'culturally safe space' for students, a student ambassador program, and community-building events. All first-year students now engage directly with indigenous community members and elders throughout a six-week cultural contextualization course and the Four Seasons of Reconciliation on-line course.
- A Permanent Indigenous Engineer-in-residence at the University of Calgary provides a role model for students and is 'engaged in meaningful conversations and learning opportunities' with all levels of leadership within the school.
- The Engineering Access Program, or ENGAP, at the University of Manitoba provides custom resources to Indigenous students including academic supports, a staff counsellor, financial aid, and community building activities.
- Indigenizing Engineering work at The University of British Columbia Okanagan Campus aims to identify areas throughout the engineering curriculum where Indigenous content and delivery can be infused.

TEXTBOX (ITALICS TO INDICATE, NOT ITALICS IN TEXTBOX): Seniuk Cicek et al.'s 2020 paper, Indigenous Initiatives In Engineering Education in Canada: Collective Contributions, identified that work is happening within CEAB accredited engineering programs across Canada towards "[advancing] Indigenous engagement and achievement and demonstrat[ing] respect and recognition for Indigenous Peoples in engineering education" [49, p. 3]. The identified initiatives were themed into 11 categories:

- *Engineering/STEM Outreach;*
- *Engineering Access & Bridging Programs or Mechanisms;*
- *Provincial & National Collaborations/Presence/Research in Engineering & Engineering Education;*
- *Committees/Councils/Strategies in Engineering;*
- *Engineering Faculty & Institutional Positions;*
- *Engineering Curricula;*
- *Elders/Knowledge Keepers/Indigenous Community Members involved in Engineering Education;*
- *Engineering Student Organizations;*
- *Engineering Faculty Training/ Workshops; Engineering Student Training; and*
- *Indigenous Culture in Engineering' [49, p. 4].*

TEXTBOX (ITALICS TO INDICATE, NOT ITALICS IN TEXTBOX; can be placed earlier in this section): A foundational principle of their paper provides a glimpse into the level of change that may come, called "achiev[ing] Etuaptmumk – Two-Eyed Seeing [Elder Albert Marshall's term] – creating an 'ethical space' in engineering education where Indigenous ways of knowing and being are recognized and respected, and taught in partnership with western perspectives, ultimately strengthening engineering education"

[49, p. 6]. With the development of specializations and courses that focus on Indigenous ways of knowing, as well as other initiatives described above, a picture of the future of engineering education is emerging that includes "diverse Indigenous initiatives and strategies that broadly span the curricula and culture, fortified by deeply rooted, concentrated and exclusive Indigenous initiatives stratified across mental, physical, emotion, and spirit aspects as guided by the Sacred Hoop or Medicine Wheel…[that] will enable …[Indigenous knowledges to] permeate the western colonial educational system" [49, p. 6].

As commitments to Indigenous ways of knowing and ways of being continue to grow in engineering programs across Canada, there will be changes to engineering education learning environments, requirements of leadership, faculty qualifications and curricula, as already seen in the examples above. As an example, consider land-based learning, where learning occurs with Elders and knowledge keepers on the land. Land-based learning is already part of the curriculum in Canadian law schools and part of engineering outreach (e.g., UBC's Geering Up Engineering Outreach Land Based Programming). At the undergraduate degree level, land-based courses will raise questions of: who is teaching and who can teach given Indigenous knowledge systems and national qualification requirements? How will learning, teaching, and assessment of traditional ways of learning including observing the land and storytelling be classified and reported for accreditation while being culturally respectful?

In an Indigenous Land-Based STEM Education paper [50], Tom Mugford, Program Development Specialist for Indigenous Education, Government of Newfoundland and Labrador, is quoted as saying that "Calling land-based education 'alternative' is a barrier." Though considering a youth education context, the same report notes "Accreditation, reporting, and funding procedures and structures can be overwhelming when these do not align with an Indigenous worldview. Education systems prioritize accredited programs and curricula decisions are based on non-Indigenous models."

6. Well-being and Whole Student

There is emerging attention to students' well-being, strengths and needs as a whole person. This emergence is in addition to and in conjunction with addressing inequities that differentially impact student well-being. Mental health is defined by the World Health Organization as 'a state of well-being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community.' [51, para. 3]

The framing of engineering education workload has shifted from a rite of passage to being listed as a stressor. In a recent study, achieving sufficient grades for second-year placement and the associated workload were found to make up 40% of the stressors throughout the academic year [52]. Further tracking of 30 students every week indicated 'a small, gradual deterioration in student wellbeing throughout the academic year' for first year students [52, p. 7]. While being away from family was included in the analysis, taking care of family was not measured or considered. Students with families, including mature students, or students with siblings or parents requiring care face additional challenges and considerations for well-being.

TEXTBOX: A checklist and considerations for enhancing student well-being by E-CORE was presented [53] at 2020 CEEA-ACEG conference. Their presentation identifies three factors for enhancing student well-being: "1. BELONGING & SOCIAL INCLUSION: Students' well-being is supported when they feel connected to their instructors and peers; 2. LEARNING WELL: Students' well-being is supported when they are motivated to learn and when they feel that they are learning effectively. 3. WHOLE STUDENT: Students' well-being is supported when instructors recognize that students have lives outside academics" [53, slide 3]. With consideration of the whole student, strategies for recognizing students have lives outside of their academics included: "Not requiring proof from students experiencing a crisis; Offering deadline extensions; Incorporating flexibility into the grading scheme; and Setting deadlines to encourage work-life balance" [53, slide 8]. Raises the question of how could this advised flexibility and differentiation be considered valued and not a liability in accreditation criteria?

Trend 3. Student-Centered Engagement with Complex Problems

The nature of engineering problems is shifting with greater open-endedness and complexity, diverse teams and partners, and considerations for sustainability and equity that require the integration of both technical and behavioural skills, also called interpersonal or professional skills. 'Engineering has traditionally addressed unintended consequences of technological development (e.g. air pollution), with 'end-of-pipe' technologies (e.g. scrubbers), but for a more sustainable world, the root causes of wicked problems [such as homelessness] must also be addressed and engineering students must learn to analyze and engage with these root causes.' [54, p. 3]

Engineers operate in an interconnected world, 'necessitat[ing] a global perspective, to enable them to work together with diverse partners to tackle the world's problems in a sustainable manner' [55, p. 1]. Complementing this shift is the 'growing trend in engineering education to increase … societal awareness among the engineering graduates' [56, p. 1]. Furthering the capacity of graduates to meet societal needs requires an increased focus on sustainability [57, 58, 55], a complex problem that requires a multi-disciplinary lens. In addition, 'Engineering graduates increasingly find that they are part of teams that draw a multi-disciplinary membership across a broad range of cultural, socio-economic, and linguistic backgrounds,' which requires our students to have inter-cultural competencies and greater self-awareness [55, p. 1].

The revised definition by the Canadian Engineering Accreditation Board (CEAB) for Engineering design specifies:

> 'a process of making informed decisions to creatively devise products, systems, components, or processes to meet specified goals based on engineering analysis and judgement. The process is often characterized as complex, open-ended, iterative, and multidisciplinary. Solutions incorporate natural sciences, mathematics, and engineering science, using systematic and current best practices to satisfy defined objectives within identified requirements, criteria and constraints. Constraints to be considered may include (but are not limited to): health and safety, sustainability, environmental,

ethical, security, economic, aesthetics and human factors, feasibility and compliance with regulatory aspects, along with universal design issues such as societal, cultural and diversification facets' [59, p. 10].

Engineering education is thus tasked with preparing students to engage in this creative, multidisciplinary, iterative, and open-ended design process to solve complex problems.

Within engineering education internationally, *The global state of the art in engineering education* report [9] noted 'a move towards socially-relevant and outward-facing engineering curricula. These curricula will emphasize student choice, multidisciplinary learning and societal impact, as well as expose students to a breadth of experiences outside the classroom, outside the traditional engineering disciplines and across the world' [9, p. 39]. In addition, for student-centered learning, 'the interview feedback made clear that the majority of thought leaders anticipated that 'team-based, hands-on student learning that responds to the needs of society and industry' would underpin the world's leading engineering programs in the decades to come' [9, p. 35]. With the increasing prevalence of engineering education research in Canada and abroad [60], and the investment in teaching-focused faculty positions in Canada [61], the incorporation of learner-centered pedagogical practices may increase, though as of now, the vast majority of lecture hours have been passive, and heavily focused on instructor-centered lecture-style courses [62, 63]. Problem-sets within engineering education can display a range of problem set construction and level of realistic replication of an engineering practice context for some, but not all.

There are well-established learner-centered educational experiences in engineering education such as coop/internship opportunities [64, 65] and hands-on laboratory courses [66, 67] that can be found in almost every engineering program in Canada. Active Learning is another umbrella term for student-centered pedagogical practices that engage students cognitively, affectively, and socially [26, 27].

There are also multiple learner-centered practices that are well established in higher education and have been used within engineering programs. These practices include:

- **Gamified education**
  Gamification is a pedagogical tool in which instructors 'use game elements like point systems, leaderboards, badges, or other elements related to games into 'conventional' learning activities in order to increase engagement and motivation' [68]. Engineering education examples*:*
  - Gamifying a first-year chemistry course for engineers [69]
  - Gamifying a first-year engineering design course [70]

- **Flipped delivery**
  Flipped learning gives students the opportunity to learn at their own pace by moving instructional content to videos and media (usually delivered through an online learning platform) to be watched outside of class and using class time for hands-on activities and discussion [61]. Engineering education examples:
  - Designing classroom space for active learning (i.e., flipped classrooms) [71]

- Flipped delivery of an introductory programming course [72]

In particular, the integration of behavioural (e.g., teamwork) and technical skills, experiential learning in realistic contexts, and problem/project-based learning were found to be broadly used across institutions. These are discussed in more detail below.

7. Integrating behavioural and technical skills

While engineering curricula remain largely technical and 'characterized by an artificial 'border' that distinguishes technical expertise from the professional skills needed to solve society's most pressing problems' [73, p. 1], engineering education is expanding to incorporate these skills. The skills are called behavioural skills in this report, they are also known as interpersonal or professional skills. 'The Engineering profession is complex and interdisciplinary, and students today must learn how to integrate skills across technical and social disciplines' [74, p. 1]. Across the current CEAB Graduate Attributes, there is an 'overall agreement that engineering education should not only address science and engineering [technical skills] but also the social, ethical, and organizational [skills]' within engineering practice that engineering students need to be successful in an increasingly complex and globalized workplace [75, p. 1].

Winberg et al. found in their study, *Developing employability in engineering education: a systematic review of the literature*, that 'both stronger engineering knowledge and stronger professional skills … were achieved through embedding professional skills in mainstream engineering subjects, such as including problem-solving tasks and projects across the engineering curriculum' [76, p. 26], which is happening in engineering courses across Canada. Examples of instructors integrating behavioural (Winberg's *professional*) skills into engineering curricula include:

- mental wellness and lifelong learning [77]
- teamwork and communication [78]
- conflict-resolution [79]
- empathy [80]

Internationally, improving empathetic communication was the focus of four sequential seventy-five-minute modules at the University of Georgia as part of developing professional skills [81]. In addition, emotional intelligence capabilities [82] were highlighted in the Australian Council of Engineering Deans' report. Walther et al. 'argue that empathy is important in a range of engineering graduate outcomes and professional practice applications, and that students 'need explicit training in empathy to offset the analytic cognitive bias of undergraduate engineering degree programs'' [83, p. 31]. Further examples of programs at the University of Western Australia and several other American universities are described by Sochacka and colleagues [84].

8. Experiential learning

Experiential learning is 'the application of theory and academic content to real-world experiences, either within the classroom, the community, or the workplace, which advances program or course-based learning outcomes' [85], and a 'process whereby knowledge is created through the transformation of experience' through a cycle that includes an experience and reflection [86].

Engineering programs have many courses that are well suited to experiential learning opportunities, some of which are commonly found in Canadian institutions, such as: work-integrated learning experiences (e.g., co-op/internships), 'hands-on' laboratory education, and design project courses that see students working on 'real-world' challenges [87, 88].

Experiential learning opportunities can, and in the case of capstone design projects often do, include partnerships with community or industry organizations. Experiential learning can encourage students' understanding of the real-world impact of their course-work as early as their first year. One example of such a partnership is at the University of Prince Edward Island where an instructor partnered with the Atlantic Veterinary College to develop a design project for first-year engineering students to design and construct bat houses that remotely collected data on individual bats within a colony [89]. Additional recent examples found in CEEA-ACEG proceedings include:

- A University of British Columbia First Year Biomedical Engineering Laboratory Course incorporated problem-based learning with semi-structured experiential learning for new students who were in the early stages of developing discipline-specific knowledge.
- York University's Second Year Civil Engineering Materials Course incorporated an experiential learning opportunity, constructing and loading a small bridge, in a virtual setting.
- McMaster University developed a course, in partnership with students, that gave students credit for extracurricular involvement.

Students can also devise their own experiential learning opportunities and obtain credit in some cases, through student-led, individually-created courses (SLICCS). Developed at the University of Edinburgh, SLICCS provide a 'scalable and flexible experiential learning and assessment framework' that is currently open-source [90]. One example of a SLICC introduced in Canada is a 'Foundations of Venture Creation' course at the University of Waterloo, wherein students 'commit to starting a venture' and are guided through the process.

9. Problem/Project Based Learning

Problem-based learning is defined as any learning environment wherein the problem drives student learning, that is when 'a problem is posed, so that the students discover that they need to learn [something new in order to] solve the problem' [91, para. 3]. Project-based learning is when students take a real-world problem and find a solution to that problem; this form of learning is focused more on the application of knowledge than problem-based learning which is focused on the acquisition of knowledge [92]. Problem-based learning and project-based learning are used regularly in engineering courses, and while they are distinguished by their outcomes, there is significant overlap between the two concepts. Both pedagogical practices encourage self-direction and collaboration and can have a multidisciplinary orientation.

Project-based learning in engineering classrooms often includes a requirement to solve 'context specific cases and open ended challenging problems' [88], and the terms are used interchangeably in engineering education literature. Project/problem-based learning are well-established pedagogical approaches within engineering curricula as they are natural components of design classes, for example:

- Simon Fraser University's engineering design course project consisted of students 'designing, modeling, and simulating a renewable energy system that solved a particular problem within a predefined scenario that changes year to year.
- Polytechnique Montréal's first year engineering student design challenge allows students to learn and apply mechanical design methodologies in authentic iterative design practice.

Project and problem-based learning have many benefits to student learning: 'Project-based learning allows students to simultaneously develop technical understanding, creativity, and interest. Furthermore, their heightened interest improves other perceptions like their enjoyment of the topic, the subject's value, and their career aspirations in the field' [72, p. 6]. One Canadian engineering education research team noted that 'one of the primary objectives of PBL approaches is to transform the labs to be student-centered, where the outcomes and objectives are largely determined by the students, to create an environment of self-directed learning' [93]. This also encourages the development of professional skills such as time-management and critical thinking.

Project and problem-based learning are also well suited to and often incorporate team-based learning in engineering education in Canada. An emerging practice is to allow interdisciplinary teams within this space, which can 'allow students to 'break out from their disciplinary silos,' offering them critical insight into the role and place of their own engineering discipline, as well as the tools 'to work effectively with people from a range of backgrounds and perspectives'' [9, p. 22]. Interdisciplinary projects can be housed within an engineering course, a cross-listed course, or a course outside engineering.

Similar to experiential learning opportunities, problem/project-based learning experiences are also well suited to partnerships with community and industry partners [87, 94]. Recent growth in software platforms connecting industry/community with students and faculty members seeking course projects has the potential to increase the number and national range of community partnerships.

Conclusion

Overall, this report informs future decisions about the engineering accreditation system by describing the current landscape of engineering education and identifying trends that indicate what the future of engineering education might look like in Canada.

The three trends of increased flexible and assessed pathways; open and inclusive culture; and student-centred engineering education are interconnected. The changes necessary to address equity, diversity, and inclusion will need to be substantial and attentive to other trends [5, 9]. Considering these changes as a whole allows for leveraging synergies and addressing disproportionate barriers for marginalized or underrepresented groups when acccessing student-centered activities and engineering education [29]. In considering the changes in engineering education, 'This transformation must begin with a deliberate effort to build an inclusive and collaborative engineering community that spans disciplines, gender, ethnicity, race, and sexual orientation' [5, para. 6].

As the field of engineering education research in Canada and society both continue to evolve, with increasingly complex challenges facing engineers of the future, further shifts in engineering are expected [11, 12, 20]. There is recognition that 'the scholarly work going on in engineering education is not translated back into the lecture room' [9, p. 13] and that traditional didactic approaches are still prevalent [1, 16]. Still, change is building. Current and emerging practices in Canadian engineering education reflect an education system at the beginning of a significant period of accelerating change that is likely to include: shifting teaching methods, increasing programmatic flexibility, changing culture towards greater diversity, inclusion, equity and Indignization, and a student-centred focus on skill-development, expanding partnerships and greater personalization. These changes are echoed internationally, as well.

The questions that arise for consideration by the Engineering Education Task Force, Steering Committee and Stakeholders are:

1) where are these identified current and emergent engineering education practices most likely to stretch the current accreditation system's design or be restricted by its current design?
2) What are the implications and considerations? and
3) What is occurring in the engineering education ecosystem that provides further context for these trends and considerations for the strategic priority?

About the Consultants: Higher Education and Beyond

Higher Education and Beyond's experienced and qualified facilitators and researchers offer evidence-informed decision-making, professional development design, evaluation capacity building, and inter-perspective knowledge facilitation for organizational success and stakeholder engagement within and beyond higher education.

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Appendices

Appendix 1: List of Engineering Education in Canada workshop participants

Appendix 2: CEEA-ACEG Proceedings Coding and Report Coding (excel) with four tabs: 2a. List of Topics across CEEA-ACEG, Reports and the Workshop Sources; 2b. CEEA-ACEG 2020 & 2021 coding; 2c. Future of EE Reports and statements; and 2d. Coding criteria.