

Engineering education in Canada

William E. White

Ryerson University
Toronto Canada

ABSTRACT: The practice of engineering in Canada grew out of the military, as has been the case in many parts of the world. Not surprisingly, the first non-military engineers were *civil engineers*. The first formalised engineering education in Canada was given at the University of New Brunswick circa the mid-1800s. Since that time, the numbers and diversity of courses in engineering has increased enormously. This article describes the current state of engineering education in Canada, focusing on academic and experiential learning requirements, accreditation criteria and innovations in interactive engineering design. Some statistics are provided as well, including comparisons with engineering programmes elsewhere in the world. The health of engineering in Canada is excellent and opportunities for graduates into the foreseeable future are reasonably good.

INTRODUCTION

This article provides an overview of engineering education in Canada. Five main elements are discussed, as follows:

- The numbers and variety of university engineering programmes.
- The curricular requirements for accreditation by the Canadian Engineering Accreditation Board (CEAB).
- Innovations in the delivery of education.
- A brief comparison of academic and experiential requirements with programmes offered elsewhere in the world.
- An introduction to the Canadian Design Engineering Network (CDEN).

ENGINEERING EDUCATION IN CANADA

Accredited engineering programmes in Canada are diverse in number and kind. A review of the latest statistics provided by the CEAB shows that there are more than 30 educational institutions offering in excess of 200 accredited undergraduate engineering programmes leading to the baccalaureate degree [1]. The five most popular programmes, judged on the basis of the numbers offered across the country, are listed in Table 1. Those programmes of intermediate popularity are displayed in Table 2.

In addition to these, there are almost 40 unique single listings, including such programmes as Bio-systems Engineering, Petroleum Engineering and Forest Engineering, to name a few. In 2000, the latest year for which statistics are available, there were 43,000 undergraduate and 9,000 graduate students enrolled in engineering programmes across Canada, from which 8,000 baccalaureate degrees were awarded. The graph in Figure 1 provides a statistical summary of the numbers of graduates by year in the various engineering disciplines since 1942 [2].

Table 1: The five most popular programmes, judged on the basis of the numbers offered across the country.

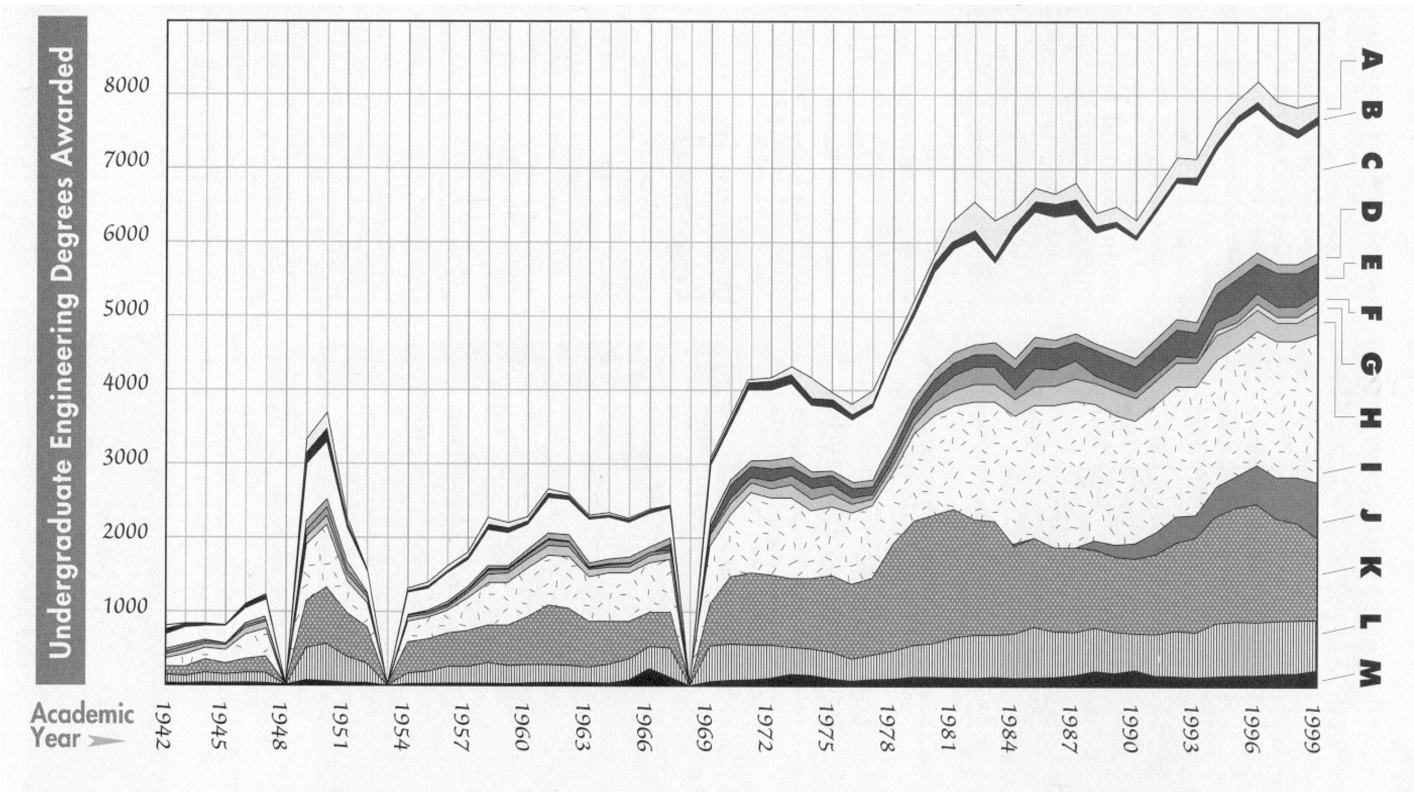
Programme	Number
Electrical	28
Mechanical	27
Civil	25
Chemical	21
Computer	15

Table 2: Programmes of intermediate popularity.

Programme	Number
Geological	11
Industrial	9
Eng. Physics	9
Mining	8
Metallurgy	8
Materials	5
Environment	4
Mineral	3
Aerospace	2

CURRICULAR REQUIREMENTS

Table 3 summarises the minimum curricular elements in terms of academic units [XXX] required by the CEAB if an engineering programme is to meet or exceed the minimum requirements for accreditation [1]. Also shown in this table are possible curricular contents for programmes that, institutionally, may desire a focus on basic and engineering



Note: A: Other, B: Mining/Mineral, C: Mechanical, D: Met/Materials, E: Industrial/Manufacturing, F: Geological, G: Environmental, H: Engineering Science, I: Electrical, J: Computer, K: Civil, L: Chemical, M: Biosystems.

Figure 1: Engineering gradates within Canada (1942-2000).

science, or emphasis on the design aspects of engineering, or, in the last column, a balanced focus between engineering science and design. Such comparisons demonstrate that the focus of the programme content is very much a decision by each engineering school and that the nature of the CEAB criteria are sufficiently flexible such that programmes can meet them while still reflecting the unique emphasis desired by the particular universities and engineering schools.

Table 3: Minimum curricular elements in terms of academic units [XXX] required by the CEAB.

CEAB AU Content	Science Focus	Design Focus	Balanced Focus
Computer Study [225]	250	350	400
Mathematics [195]	250	200	200
B/Sciences [225]	500	250	400
E/Science (ES) [225]	750	250	500
E/Design, (ED) [225]	250	950	500
ES & ED [900]	1,000	1,200	1,000
Other [245-445]			
Programme AU [1,800-2,000]	2,000	2,000	2,000

The CEAB also wants to ensure the adequate integration of material to specifically address the subjective design decision-making processes that are the hallmark of accredited engineering programmes. Specifically, engineering design integrates mathematics, basic sciences, engineering sciences and complementary studies in developing components, systems and processes to meet specific needs.

The CEAB has defined engineering design to embody the following:

It is a creative, iterative, and often open-ended process subject to constraints which may be governed by standards or legislation to varying degrees depending on the discipline. These constraints may be related to economic, health, safety, environmental, social, or other pertinent factors. It is the clever integration of material into the learning process that needs to be strengthened, not the introduction of more subject matter, such as safety, the environment, and-so-forth, in isolation of the real engineering that attracts students to our universities [3].

It can be shown that within these criteria, educators can meet accreditation requirements while still retaining a unique flavour or dimension to the type of engineering graduate deemed important to that institution.

CHALLENGES

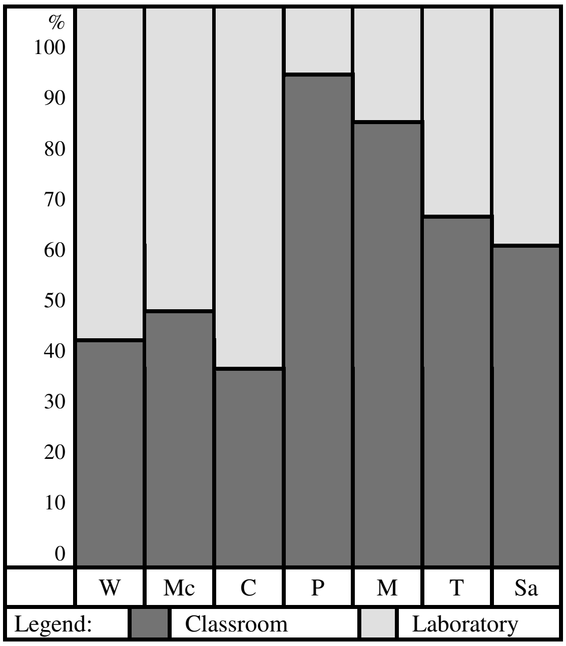
However, notwithstanding these statements and comparisons, there are significant challenges and constraints imposed upon educators. These may include, but are not necessarily limited to:

- The four-year degree for traditional programmes.
- Shrinking resources.
- Incoming student quality.
- Culture backgrounds.
- Belief that each concept must represent a course.
- Science-based teaching.
- Design and Manufacturing.
- The co-op/internship role.
- The reward system for faculty.
- Partnerships with the CEAB and others.

There are other challenges too, depending on the type of engineering graduate an institution may wish to produce. Engineering education is intimately tied to knowledge, not for knowledge's sake, but to have the tools to adequately address specific societal needs. Educators must continue to challenge students. The delivery format must promote innovation. Furthermore, students must learn where and how to find relevant information and how to apply it creatively.

The science-based lecture, laboratory and tutorial format has served engineering educators well in the past, but modern society demands new and novel means to provide a relevant education, especially in light of new and emerging multimedia and communications technologies. Successful models require champions: they take effort. Well-designed laboratory sessions to complement the lecture material are very important and educators must continue to provide such experiences for students.

Figure 2 compares laboratory versus classroom time for some mechanical engineering programmes on a global scale. Canadian universities, along with CalTech in the illustrations given, seem to have a very good balance between classroom and laboratory time.



Note: W: Waterloo, Mc: McGill, C: CalTech, P: Paris, M: Monterrey, Sa: Satjo, T: Tijuana

Figure 2: International comparisons of laboratory versus classroom time in Mechanical Engineering programmes [2].

Experiential learning is also becoming increasingly important. Cooperative and internship programmes are increasing in numbers in Canada. A majority of engineering schools now provide opportunities for their students to work in industries and businesses relevant to their chosen discipline of study. The co-op form of education, wherein students alternate classroom study semesters with work placement semesters, was first implemented by the University of Waterloo in the Kitchener-Waterloo region of Canada. Students in these cooperative education programmes may gain up to 20 months of related work experiences during their undergraduate study period. This model increases the minimum timeframe to complete the degree programme from four to five years.

The internship model differs from the co-op model in that students are given the opportunity for work term placements of 12 to 16 months, either following the second year of full-time study or at the end of the third year of full-time study. This model of experiential learning in Canada was first introduced by the University of Toronto.

This form of integrated experiential learning also extends the timeframe for degree completion from four to five years. Universities across the world are increasingly establishing collaborative agreements with businesses and industries as shown in Figure 3. Canadian universities seem to be affording good opportunities for students to gain experience through cooperative education and internship programmes.

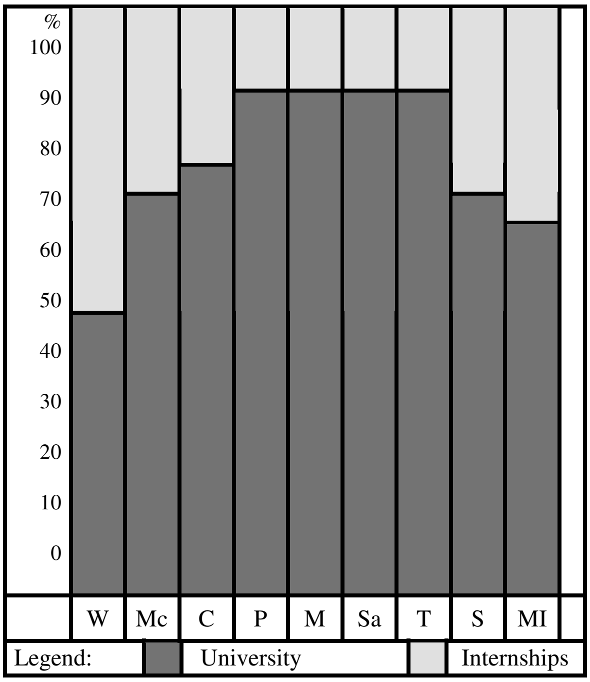


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Figure 3. International comparisons of internship versus university time in mechanical engineering programmes [2].

Total curricular content of Canadian universities in engineering education is compared globally to other university offerings in Figure 4. The *other* category includes mathematics, basic sciences, arts, humanities, social sciences, etc. It can be seen that Canadian universities seem to have less content and emphasis on the arts, humanities and social sciences than their counterparts around the world. Could this mean that Canadian students receive a less broad education?

INNOVATION

There are now numerous examples of innovations in the delivery of education in Canada wherein the new and emerging multimedia and communications technologies have been integrated effectively into the education processes. However, space prohibits the coverage of all aspects.

The Interactive Learning Connection-University Space Network (ILC-USN)

One of the earliest examples was the establishment in 1994 of the Interactive Learning Connection-University Space Network

(ILC-USN). This has grown to be an effective network of several Ontario-based universities that collaborate each semester in the Internet delivery of a Spacecraft Systems Design Course [4][5]. The full history and activities of the ILC-USN can be found on the Internet (see Figure 5) [6].

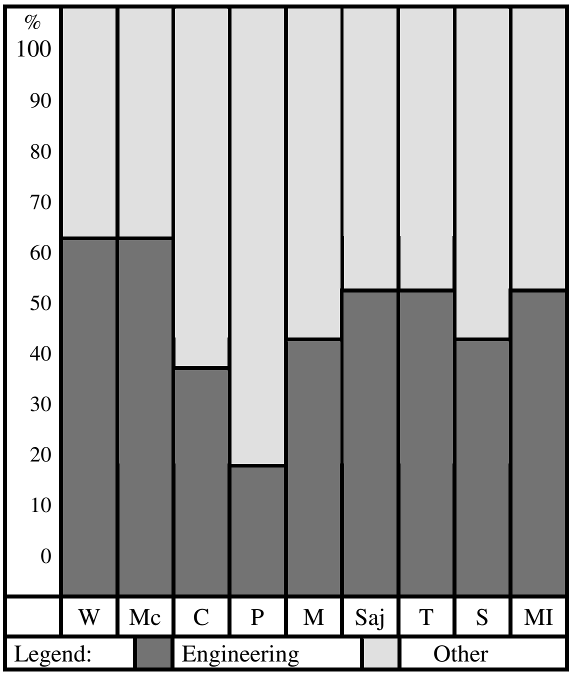

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Figure 4: International comparisons of engineering curricula for mechanical engineering programmes.

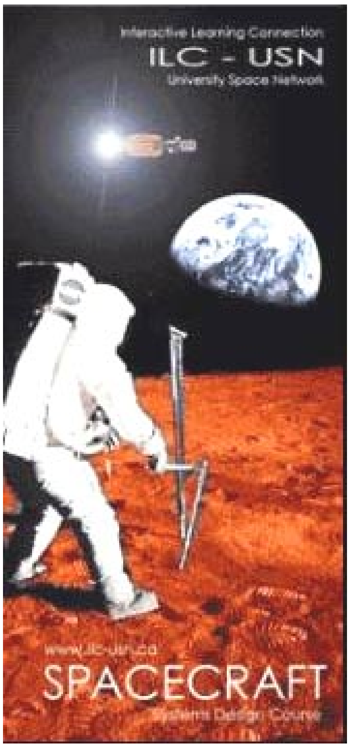

Figure 5. ILC-USN Spacecraft Systems Design Course [6].

The full learning module content is available to students who are provided with the necessary identity and passwords to log on. The course content is also provided to student registrants on CD-ROM so that the media rich content, including video and audio, can be viewed without any Internet bandwidth restrictions. The course is hosted on a first generation Web site using HTML in frames, with animations, images, audio and video. Password protected threaded discussion groups are provided for individual student teams. A general discussion group is used by all teams. Students interact with each other and professors both synchronously and asynchronously.

The course content was developed by professors at several universities, and students interact with the professors directly, irrespective of geographic location, when they are undertaking and completing work relevant to the professors' fields of expertise. In addition, links to student team Web sites and Internet resources are provided. The results of the students' works can be seen by visiting the Web site [6].

The students are challenged each semester with a major design mission and these missions may also be viewed on the Web site for interested readers [6]. Often, the major design mission is defined by industrial partners. In fact, the current mission, a Mars Scout Mission System (MSM), has been given to the students by MD-Robotics, which is the former SPAR Aerospace Corporation.

The fact that students work on current and emerging industrial projects helps to stimulate and motivate them. It can be seen by examination of the students' work over the years that this is a project-based course and the students see the relevance of all theoretical material right at the outset. Thus, students are stimulated and motivated to a very high level. Independent assessments have confirmed that the students are provided with rich, value-added, learning experiences and these assessment reports are also provided on the Web site [6].

The ILC-USN does not compromise the social dimension of the education processes. People are connected to people. Project Based Learning (PBL), peer-to-peer learning and the presentation of the theoretical materials in ways that take into consideration the various learning styles and characteristics of students have been integral to the superior performance and scholastic achievements of the students involved.

To summarise briefly, the ILC-USN has been successful as a networked, distributed educational initiative for several reasons, namely:

- Through the sharing of resources and expertise.
- Through the use of engaged learning where students benefit from team dynamics, access to, and use of, unbounded sources of knowledge.
- By direct access to domain experts, including access to practising engineers and real life problems through tasks provided by industrial partners.
- By challenging students to a very high level right from the outset.

The major design initiative is articulated early so that all students can relate to the theoretical concepts of systems design, orbital mechanics, propulsion systems, robotics, communication systems and so forth. Finally, throughout the development of the ILC-USN collaboration, educational and learning goals have been paramount and the new media and communications technologies are used only as an aid to attaining these goals.

THE CANADIAN DESIGN ENGINEERING NETWORK (CDEN)

A very recent initiative in Canada has been the establishment of the Canadian Design Engineering Network (CDEN) (see Figure 6). The CDEN is an attempt to link all engineering schools across the country with the goal of sharing courses, expertise and resources in engineering design. In this context, the ILC-USN design course described above has been made available, to and integrated into, the CDEN. Full information on CDEN may be found at on the Internet [7].

The CDEN/RCCI network will enable the communication of best practices between schools, promote the production and sharing of courseware, help inject more real design experiences into universities and allow all schools to access the best available expertise in areas of detailed interest. The network will facilitate the joint development of multi-discipline design related material (courseware modules), including lectures, case studies and open-ended design projects.

The CDEN's vision embodies the full sharing of expertise, resources and knowledge between schools for the benefit of all Canadian students. In fact, the CDEN may be seen as an expanded ILC-USN, but without the narrower scope of spacecraft design. To facilitate the timely development of the CDEN, the Natural Sciences and Engineering Research Council of Canada (NSERC) has provided funding to support and establish NSERC/CDEN Design Chairs to be located at universities right across Canada. Currently, eight such Chairs have been established, these being located at the Universities of Guelph, Western Ontario, Calgary, Manitoba, Sherbrooke, New Brunswick, as well as Ecole Polytechnique in Montreal and DalTech in Nova Scotia. Processes are currently underway to establish an additional eight NSERC/CDEN Design Chairs.

The CDEN, being a relatively new venture in collaborative engineering design education, will require some time yet before its full value can be realised. However, provided that the interests of students and the goals of *student-centred* learning are kept in the forefront, there is no reason to believe that CDEN cannot be as successful, or even more so, than the ILC-USN and other ventures.

SUMMARY

An overview of the current status of engineering education in Canada has been given in this article. Engineering education in Canada has been contrasted and compared to programmes offered elsewhere in the world. Examples have been given showing some of the newer innovative design education practices that are being developed to provide relevant design education to Canadian students.

It is the intent of Canadian educators to continue the evolution of Canadian programmes to strive to provide the best in innovative practises so that graduates will always be able to be productive members of society in whatever arenas of practice they might choose.

Figure 6: Logo of the Canadian Design Engineering Network (Réseau Canadien de la Conception en Ingénierie).

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