

## **Ecosystems of Entrepreneurship in Canadian Engineering Faculties: A Systematic Map**

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The economic turbulence of the 21st century is changing the engineering career landscape. Large firms face great challenge in boosting the economy and creating more jobs amidst uncertain economical forecast. Engineers today need innovation, leadership and business skills more than ever. Engineering schools are aware of the rising demand of engineers to learn about entrepreneurship and entrepreneurship programs for engineers are becoming a trending topic. This paper explores the different ecosystems of entrepreneurship offered at faculties of engineering across Canada. We explore two research questions in this paper: a) What is the growth, in demand and availability, of entrepreneurship courses in engineering schools, and b) What are the different components of an entrepreneurship ecosystem in engineering faculties today. The intent of this research is not to compare which program is better; rather, it is to explore the different ways of how entrepreneurship is taught in engineering schools. By providing a systematic map of the current entrepreneurial landscape in engineering faculties, this research can benefit professors and program directors who are building entrepreneurship courses and programs for engineering students, and to researchers who are studying the impact of academic entrepreneurship on engineering education.

Keywords: academic entrepreneurship, engineering education, entrepreneurial ecosystem

## **I. A Brief Background on Development in Engineering Education**

Engineering education research has significantly developed in the past few decades. Engineering researchers have noted that relying on quantitative empirical methodologies in research is not sufficient (Olds, Moskal, & Miller, 2005). Quantitative research is still the dominant methodology in much of engineering education research. However, engineering education researchers have started using more qualitative and mixed methodologies, such as: surveys, interviews, conversational analysis, observation, ethnographies and meta-analyses. Due to the high complexity of the issues related to engineering education reform, a methodologically-strict research is bound to neglect some perspective. The diversity of the problems we face in engineering education today demand diversified approaches. Great breakthroughs have happened in tackling problems of engineering education when researchers diversified from the traditional

research methods (Bjorklund & Colbeck, 2001; Clair & Baker, 2003; Gillet, Nguyen Ngoc, & Rekik, 2005; Haller, Gallagher, Weldon, & Felder, 1999; Kadiyala & Cynes, 2000; Laeser, Moskal, Knecht, & Lasich, 2003; Mayo, 2007; Tonso, 1996). Methodologies should not dictate the research questions, but the opposite is true. This paper looks at the integration of entrepreneurship in engineering faculties as means of improving engineering education.

While there is recent research on entrepreneurship courses in engineering education in the US (Gandhi, Beruvides, Taghizadeh, & Cross, 2016), the studies of entrepreneurship across engineering faculties globally are very limited, and the ones that are specific about Canada, are quite outdated. The most recent Canada wide survey on entrepreneurship course offerings at engineering faculties was conducted more than fifteen years ago (Menzies & Paradi, 2002). This study aims to bring the data up to date, and extrapolates on the previous research to include new insights.

## II. Purpose and Research Questions

Several researchers have explained thoroughly the reasoning behind the importance of having entrepreneurship course offerings at engineering faculties, and why are they different than entrepreneurship courses at business schools (Blais, 1997; Gartner & Vesper, 1994; K. H. Vesper & Gartner, 1997; Karl H Vesper & McMullan, 1988). The purpose of this research is to map the entrepreneurship landscape in engineering faculties across Canada. The research questions are:

- a) What is the growth in demand and availability of entrepreneurship courses in engineering schools?
- b) What are the different components of an entrepreneurship ecosystem in engineering faculties?

## III. Methodology

Due to the exploratory nature of the research questions, we chose to carry this research qualitatively. There are few academic sources available about entrepreneurship in engineering faculties, mainly in the form of self-reported case studies (Frank & Strong, 2013; Jarrar & Anis, 2016; Stiver, 2010; Tran & Paradi, 2009). To get a comprehensive picture we had to resort to primary sources of data for this research. Sources included the websites of engineering faculties, course catalogues, online timetables and course databases. To minimize inaccuracies, we

contacted professors, departmental officers and registrars of those universities for purposes of clarification and/or verification of data. This would reduce the possibility of missing a data point due to program fragmentation and the case for some invisible programs and offerings, or those that have outdated descriptions online. For our research methods we use surveys for the case studies, interviews with professors and departments, observation from websites of faculties of engineering, and meta-analysis of online course timetables.

#### a. Selection Criteria

We considered all the faculties of engineering that are accredited by the Canadian Engineering Accreditation Board (“CEAB”) (Canadian Engineering Accreditation Board, 2017).

Our methodology of filtering entrepreneurship courses involved machine search through titles and course descriptions of courses. Some courses did not explicitly state they were teaching entrepreneurship, but had entrepreneurial indications or concepts. For example, there are entrepreneurship courses in engineering faculties with the names: New Venture Design at UBC, Technology Business Plan Design at McGill, and Customer Value Creation in Technology Firms at Carleton. Several entrepreneurial terms were used as search terms through both titles and course description, and results were verified manually.

#### b. Limitations of Research

As this is a research that deals with primary data, we expected to encounter limitations in this methodology due to the accuracy of the obtained data, as terminologies across faculties may not be standardized, and some faculty websites may be outdated or missing complete information. To minimize inaccuracies, we contacted professors, departmental officers and registrars of those universities for purposes of clarification and/or verification of data. This helped reduce the possibility of missing a data point due to program fragmentation and the case for some invisible programs and offerings, or those that have outdated descriptions online.

Some business schools have offered minors in entrepreneurship for non-business majors. Some engineering faculties have offered courses in entrepreneurship that are cross-listed with a course in the business school, taught by a business professor. It should be noted that the scope of this research is on entrepreneurship programs in engineering faculties. To be fair and systematic in our inclusion criteria, we included all entrepreneurship programs that are advertised on programs

of engineering faculties, either through their websites or syllabi of engineering programs. While we understand that this might include entrepreneurship courses that are cross-listed with business schools, we tried to make a distinction between them and the courses that are fully offered by faculty of engineering. We acknowledge the effort of many engineering schools in making these entrepreneurial programs available through the joint effort with business faculties, but these entrepreneurial offerings to engineering students by business school are not fully equal in impact and experience to those that are originated from within engineering faculties.

While outsourcing the teaching of technology entrepreneurship to business faculties may be a step-ahead than not accommodating the field at all, we believe that this is something which can be improved, because the scope and methods of teaching entrepreneurship in business schools varies from those which are used in technology entrepreneurship courses in engineering schools. Also, because engineering students who take entrepreneurship courses with other students in business schools, often end up doing the technical components of the start-up as their non-engineering teammates cover the business aspects of the course, and thus engineering students may not get the full experience of entrepreneurship through those courses. As we have set our methodology to report on all entrepreneurship offerings from engineering faculties, the programs that are joint or cross-listed with business schools have been labelled them with an asterisk in our results.

#### IV. Results

Below are the synthesized results of the survey. Table 1 shows the growth of entrepreneurship courses and degrees at engineering faculties across Canada since beginning of the 21<sup>st</sup> century. We compare in it the data obtained from the last systematic map in 1998/1999 to the data we have collected for the academic year 2016/2017, and extend it by showing the current landscape of the entrepreneurial ecosystem at Canadian engineering faculties. We define innovation space as any physical space dedicated to promote and encourage innovation, such as innovation hubs, makerspaces, centres for prototyping, etc. Faculties of engineering that have established their own ecosystem, including course offerings, degrees, innovation space and funding, are highlighted in green.

Table 1<sup>1</sup> - Entrepreneurship education in Canadian engineering faculties between 1998/99 and 2016/17, rows highlighted in green indicate faculties that have an entrepreneurship ecosystem within their engineering faculty

| University                     | Undergrad Courses | Graduate Courses | Degrees | Undergrad Courses     | Graduate Courses | Degrees          | Innovation Space | Funding  |
|--------------------------------|-------------------|------------------|---------|-----------------------|------------------|------------------|------------------|--|
|                                | 1998/99 Academic  |                  |         | 2016/17 Academic Year |                  |                  |                  |  |
| University of Alberta          | 1                 | -                | -       | 1                     | -                | Minor*           | Generic*         | Competitions, grants*                              |
| University of British Columbia | -                 | -                | -       | 2                     | 1                | PhD*             | Generic*         | Competitions, seed funding*                        |
| University of Calgary          | 5                 | -                | 1*      | 2                     | 1                | Minor*           | Generic*         | Competitions, entrepreneurship week, seed funding* |
| Carleton University            | -                 | 1                | -       | 5*                    | 12               | Minor*, Master's | Yes              | Award, competitions, seed funding                  |
| Concordia University           | 1                 | -                | -       | -                     | -                | -                | Generic*         | Competition*                                       |
| Conestoga College              | -                 | -                | -       | -                     | -                | Diploma*         | Generic*         | Start-up funding opportunities, angel network*     |
| Dalhousie University           | -                 | -                | -       | 1                     | -                | -                | Generic*         | Awards, competitions, seed funding*                |
| University of Guelph           | -                 | -                | -       | 1                     | -                | -                | Generic*         | Competition*                                       |
| Laurentian University          | -                 | -                | -       | -                     | -                | -                | Generic*         | Competition*                                       |
| University Laval               | 4                 | -                | -       | 3                     | -                | -                | Generic*         | Awards*  |
| University of Manitoba         | -                 | -                | -       | -                     | -                | -                | Generic*         | Competitions*                                      |
| McGill University              | 6                 | -                | 1       | 3                     | 2                | Minor            | Yes              | Awards, seed funding                               |

<sup>1</sup> You may contact the authors for a full copy of the data.

| University                            | Undergrad Courses | Graduate Courses | Degrees | Undergrad Courses     | Graduate Courses | Degrees   | Innovation Space | Funding                                     |
|---------------------------------------|-------------------|------------------|---------|-----------------------|------------------|---|------------------|---|
|                                       | 1998/99 Academic  |                  |         | 2016/17 Academic Year |                  |   |                  |   |
| McMaster University                   | -                 | -                | -       | 3                     | 8                | UG option, Master's                                   | Yes              | Competitions                                |
| University of Moncton                 | -                 | -                | -       | -                     | -                | -   | Generic*         | -   |
| Memorial University of Newfoundland   | -                 | -                | -       | 1                     | -                | -   | Generic*         | Awards, entrepreneurial coop, seed funding* |
| University of New Brunswick           | 6                 | 3                | -       | 10                    | 6                | Diploma, Master's                                     | Yes              | Competitions, seed funding                  |
| Northern British Columbia             | -                 | -                | -       | -                     | 1*               | Minor*  | -                | -   |
| Ontario Institute of Technology       | -                 | -                | -       | -                     | -                | -   | Generic*         | -   |
| University of Ottawa                  | -                 | -                | -       | 6*                    | 2                | UG option, Minor*, Graduate Diploma*, Master's*, PhD* | Yes              | Awards, competitions, seed funding          |
| École Polytechnique                   | -                 | -                | -       | -                     | 11               | Minor*  | Generic*         | seed funding, Early-stage funding*          |
| Université du Québec à Chicoutimi     | 2                 | -                | -       | 3                     | -                | -   | Generic*         | -   |
| Université du Québec à Trois-Rivières | -                 | -                | -       | 2                     | -                | -   | Generic*         | -   |
| Université du Québec en Abitibi       | 2                 | -                | -       | -                     | -                | -   | Generic*         | -   |
| Université du Québec en Outaouais     | 2                 | -                | -       | -                     | -                | -   | Generic*         | -   |
| Queen's University                    | 1                 | -                | -       | 3                     |                  | UG option*  | Generic*         | Competitions, entrepreneurial internship*   |

| University                    | Undergrad Courses   | Graduate Courses | Degrees | Undergrad Courses     | Graduate Courses | Degrees   | Innovation Space | Funding                            |
|-------------------------------|---|------------------|---------|-----------------------|------------------|---|------------------|------------------------------------|
|                               | 1998/99 Academic  |                  |         | 2016/17 Academic Year |                  |   |                  |                                    |
| University of Regina          | 1   | -                | -       | -                     | -                | -   | Generic*         | Competition                        |
| Ryerson University            | -   | -                | -       | 5                     | 3                | UG option, Master's                             | Yes              | Awards                             |
| University of Saskatchewan    | -   | -                | -       | 10*                   | -                | UG option*                                      | Generic*         | Competitions*                      |
| University of Sherbrooke      | 2   | -                | -       | -                     | -                | -   | Generic*         | -                                  |
| Simon Fraser University       | 2   | -                | -       | 1                     | -                | UG option, Certificate                          | Yes              | Awards                             |
| University of Toronto         | 4   | -                | -       | 14*                   | -                | Certificate                                     | Yes              | Awards, competitions, seed funding |
| University of Victoria        | -   | -                | -       | 7*                    | 5*               | Master's  | Yes              | Competitions                       |
| University of Waterloo        | 1   | 1                | -       | 9*                    | 10*              | UG Option, Minor*, Graduate Diploma*, Master's* | Yes              | Awards, competitions, seed funding |
| University of Western Ontario | 1   | -                | -       | 4                     | -                | Certificate                                     | Generic*         |                                    |
| University of Windsor         | -   | -                | -       | 7*                    | 3                | Minor, Master's                                 | Generic*         | Competitions*                      |
| University of York            | -   | -                | -       | 4                     | -                | -   | Yes              | Competitions                       |
|                               | * Available in (partial or full) collaboration with another faculty |                  |         |                       |                  |   |                  |                                    |





Figure 1 – a map of Canada visualizing the growth of entrepreneurial course offerings in faculties of engineering across Canada. The green circles indicate the increase; the yellow circles indicate no change and the red circles indicate decrease. The diameter of the circle indicates the magnitude of change between academic years 1998/99 and 2016/17

## Change in Entrepreneurial Course Offerings in Canadian Faculties of Engineering

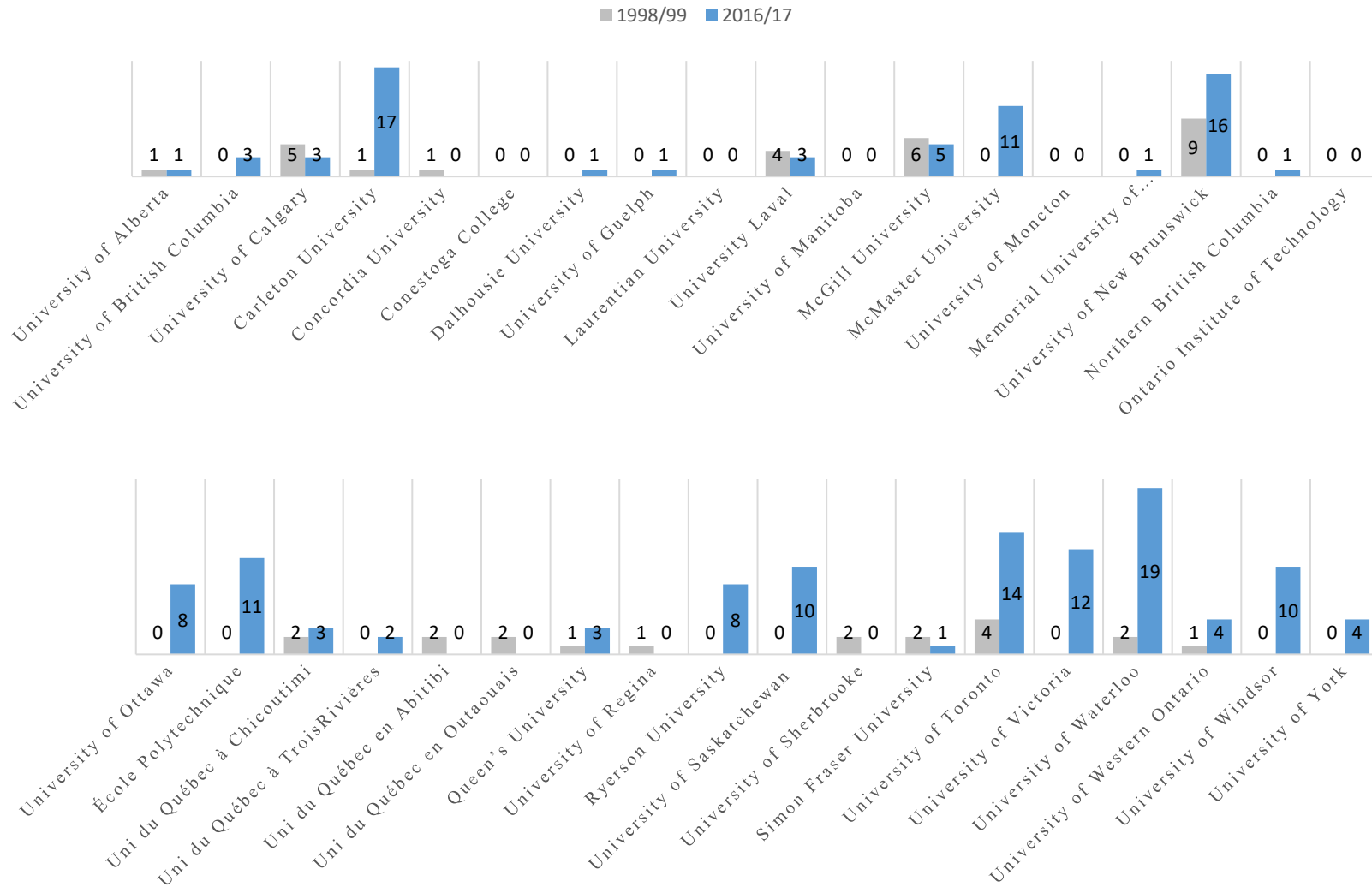


Figure 2 - Two charts showing the change in entrepreneurial course offerings in Canadian faculties of engineering

## V. Discussion

We surveyed all 47 CEAB-accredited engineering faculties across Canada and found that 35 of them have had at least one offering for entrepreneurship education between 1999 and 2016. More than 85% of the faculties of engineering have had an increase in the offerings (Figure 1), either in the number of courses and degrees, or in the entrepreneurial facilities and services on campus. Entrepreneurial competitions seem to be the most dominant pattern in growth, with prizes ranging from \$5,000 to \$100,000. While observing the entrepreneurial ecosystems in these universities, data was collected also on the availability of entrepreneurial competitions, grants, investment opportunities, incubators, accelerators, makerspaces, as well as frequency of networking events and availability of mentorship. While 11 faculties have made a dedicated innovation space, with access to funding, all other universities direct engineering students to an innovation hub on campus and to entrepreneurial programs and funding – usually at the faculty of business.

Some engineering faculties have focused on entrepreneurship courses for undergraduate engineering students (Laval, Western Ontario, York), few others have catered only to graduate students (Polytechnique). The most popular entrepreneurship programs in engineering schools seem to be a minor or an undergraduate option for engineers in entrepreneurship (total of 16 minors or options nationally). However, several faculties of engineering provide a master's degree in entrepreneurship or related field (such as Ryerson, Carleton, McMaster, Ottawa and Victoria), and one engineering school offers a PhD in Entrepreneurship (UBC).

We attempted to get the course enrollment numbers of the previous years for these entrepreneurial courses to get a closer look on the demand of the students as a function of ratio of students engaged in the entrepreneurial ecosystem to the overall student population. However, several faculties were not able to retrieve those records upon our request. Nevertheless, we believe that the significant growth of the entrepreneurial ecosystem in the clear majority of Canadian universities– keeping in mind the high costs associated with the infrastructure of this ecosystem – cannot be solely subject to administrative decision in those universities. Therefore, it can be argued that there is an increase in the demand for entrepreneurial courses and programs at engineering faculties based on the aforementioned correlation.

An important point to note is that due to the nature fragmentation of entrepreneurial programs, and the variance in visibility, ease of access to information and difference in languages and terminologies across different universities, some courses or programs may have been missed by this research. An attempt was done to validate this data through contacting departments and registrars to clarify ambiguities and verify that course information is accurate and up-to-date.

## VI. Conclusion

We conducted a survey that showed a rise in the supply and demand of entrepreneurial courses and programs at engineering faculties across Canada. The entrepreneurial ecosystems were observed and a rich variety of components and strategies were observed. Academic programs ranged from first-year workshops, to an entire PhD in entrepreneurship at faculties of engineering. Universities have invested significant amounts in building a physical infrastructure to promote innovation on campus. Almost every engineering program in Canada either has a centre for innovation or entrepreneurship of its own, or has access to a campus-wide centre. That increase in physical innovative spaces is also accompanied by increase in mentorship, entrepreneurial workshops and competitions.

## VII. Future Work

Previous studies have proposed different methods of assessment for the impact of entrepreneurship education on engineering students (Upton, Sexton, & Moore, 1995; Wheeler, 1993). Some researchers have suggested using the ratio of entrepreneurs among engineering alumni to entrepreneurs in comparison with business or general alumni population. Others used the number of start-ups founded per engineering alumni within  $x$  years after graduation in comparison with those by business or general alumni population. Some even suggested using tax data to compare their household income. While entrepreneurship is important for the economy, these criteria may not be the best way to assess the direct impact of entrepreneurship on engineering education. Not only the primary data would be speculative at best, but it uses economic measures as indicators for academic success. The two do not have to be interconnected. Rather, the assessment criteria should be more geared towards the impact of entrepreneurship on the engineering skills of the students, such as their design thinking, teamwork, project management and economics. Although some engineering attributes are simple

to assess, such as communication and teamwork, there are very few verified tools that can assess complex attributes, such as investigation and design thinking. Nevertheless, having the impact on engineering attributes as a criterion will prove to be a more universal assessment tool, because these engineering skills are essential for any engineering career, whether it was in entrepreneurship, intrapreneurship or in engineering firms and factories.

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