Education-Job Mismatch in Engineering Sector – A Canadian Case-Study

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***Abstract*— Canadian engineering job market sees growing skill-gap between demand and supply. In the meantime Canadian Engineering Accreditation Board (CEAB) initiated a paradigm shift in Canadian engineering education through introduction of its twelve outcome-based graduate attributes for undergraduate engineering programs and accreditation of undergraduate engineering programs at non-university institutes, which are primarily responsible for providing applied education for local job market. This paper presents a study on the potential of this paradigm shift in reducing education-job mismatch, and a case-study of one new non-university engineering program.**

***Keywords*— education-job mismatch; engineering education; graduate attributes; project-based learning.**

I. Introduction

There are skill-gaps in Canadian engineering job market. Section II of this paper reviews the gap. One of the main reasons of the gap is the mismatch between the graduate skills that the current Canadian engineering education system is developing and the skills that the job market needs [6]. This is called education-job mismatch.

Section III presents relevant aspects of Canadian engineering education system. There are two new things happening in engineering education: curriculum is becoming outcome-based, and non-university institutes started offering accredited undergraduate engineering programs [15]. These two actions triggered apparent paradigm shift in Canadian engineering education.

Section IV first analyzes Canadian engineering education system from the perspective of graduates' job-market, and then studies what new the non-university engineering education can bring into the engineering education system and what gaps it can fill.

Section V presents a case-study of a non-university engineering program which is also happened to be a project-based engineering program. This case-study highlights the potential of such a program in filling the gaps in job market. Conclusion on the findings has been drawn in section VI.

II. Job Market

Recent studies such as [1], [2], [3], and [4] indicated a looming mismatch between demand and supply in Canadian labour market. Reference [5] called it "*people without job and job without people*". According to [4], the skill gaps cost the province of Ontario, the most populated province and the home of largest city Toronto and the national capital Ottawa, up to 24.3 billion dollars in foregone GDP and 3.7 billion dollars in provincial tax revenues, annually.

Engineers Canada, the national organization of provincial and territorial associations that regulate the practice of engineering in Canada, found similar imbalance between demand and supply in engineering job market [6]: "*On the one hand, an abundance of Canadians seeking work as engineers, on the other hand there is an acute shortage of engineering skills.*" Two major determinants of this mismatch are regional-gap and education-job mismatch.

The regional-gap is basically the shortage of engineers of certain field of study in one region whereas abundance of the same but without job in somewhere else. Inter-province mobility is not easy as it may appear. Canada is a vast country – about ten million square-kilometers area and six thousand kilometers coast-to-coast distance. Canada is one of the most decentralized countries in the world. Provinces and territories are responsible for licensure for their engineers. Engineers from other jurisdictions need to go through some process to obtain local license.

Education-job mismatch has multiple dimensions, such as field of study, level of study, demography and globalization, occupation specific practical and design skills, and generic employability skills.

How to minimize this education-job mismatch in an effective and sustainable way? There are number of ways to address it.

One, there can be skill training programs for unemployed workers. One notable example is Ontario's 'second-carrier' program [7], which spends up to 28 thousand dollars per individual and already enrolled over 50,000 individuals [5]. About 74% of the trained workers were able to find jobs within one year of graduation [7]. However, this type of program is quite expensive and is not designed for engineers.

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Two, employers can have employee training and on-the-job training programs especially for new hires and novice employees. However, Canadian employer spend only 1.5% of their payroll whereas, for example, USA employers spend somewhere in between 2.25% to 2.8% [5]. Reference [5] also listed reasons why Canadian companies are reluctant to invest money and time to train novice employees. One of the biggest concerns is return on investment. Employers such as small and medium enterprises (SMEs) often see their employees, whom they trained to bring up to speed, leaving the company often to bigger and more well-known companies. It is also a trend that highly skilled workers, who are trained in Canada, find more rewarding jobs in bordering country USA – the biggest economy in the world. Obviously, these factors make companies reluctant to spend money for employee training [8]. Instead, companies want 'job-ready' graduates. In other words, companies expect institutes to produce new graduates with all these skills learnt [9].

Three, hiring foreign engineers is an option. However, hiring foreign engineers appears to be a short-term solution unless it is successfully tied to immigration. Most of the developed world is in the same predicament and, as a consequence, Canada faces stiff competition [5]. Leading national daily newspaper Globe and Mail reported tightening rule for foreign worker [10], which is apparently discouraging this path.

Four, immigration is a long-time tool for Canada to fill its shortage of human resource. Though it increases human capital it is so far not very effective in targeting applicants with specific skills and placing them where those skills are in demand [5]. Reality of immigration includes the following facts: immigrants are mostly concentrated to few big cities, foreign credentials are not often recognized in Canada, and language poses a problem. Besides, their skills do not readily match with market need. For example, immigrants from less-developed countries generally have appropriate level of education and job experience but are less likely to have appropriate level of skills in modern technology components, such as computer-aided design tools, which are essential for some jobs in Canada [22].

Five, the number of international students for engineering education are growing in Canada [6]. This could be an avenue to reduce engineer shortage. However, a significant portion of them leave the country after graduation [5] for a variety of reasons.

Six, creating new education programs and/or changing existing programs for producing home-grown job-ready graduates for local and regional job markets. This paper focuses on this solution.

It appears that there is an agreement from all corners on the need of higher education and training for knowledge-economy. A report of Canadian chamber of commerce [4] highlighted the importance of raising skill level in order to compete head on with the developing world. Association of universities and colleges of Canada (AUCC) published a quick fact [9] on Canada's skill-gap, which indicated the need as well.

However, the higher education should be more market-focused. Reference [6] referred to 2006 census results that show only 49% of engineering graduates employed in engineering and related occupations. Canadian individuals spent 50 thousand US dollars on average, which is about 47% of total costs, to acquire a post-secondary degree [22]. Engineering education costs significantly above the average. Though higher education develops human capital its full utilization for socio-economic growth depends on education-job matching. The education-job mismatch causes poor return on post-secondary education investment made by individuals as well as the government and society.

III. Engineering Profession and Education System in Canada

A. Education System in Canada

Like many other countries, universities in Canada are for undergraduate, masters and PhD degrees, and colleges are for a number of different programs [11] including 1-year certificate, 2-year technician and 3-year technologist programs in order to cover the whole spectrum of daytime engineering technology education. Canadian university and college systems are predominantly publicly funded institutes, which are overseen by respective ministry of provincial governments. The public universities are more autonomous than the public colleges.

As it is expected, universities are more focused on concept, principle and research (in short, more 'academic') whereas colleges are more job-market focused and 'applied'. University class size is much bigger than the colleges in order to offset cost of research [5]. Smaller class size gives the college programs greater opportunity for providing practical education and training.

In general, colleges are more closely connected to business and industries, than universities [5]. College programs are also more focused on job market in its catchment areas and surroundings. They produce 'local graduates for local market'. Many programs of Ontario colleges have program advisory committee (PAC) whose members are from, for examples, local industries and businesses, and also other institutes and organizations. The PAC acts like a 'focus group' for future direction of the program. Their feedback is often used to update and/or retune the curriculum. The market-focused education by the colleges has an edge over the university in developing employability skill. "*The more recent pattern has been for students to complete a four-year university degree and then enroll in a one- or two-year postgraduate certificate or diploma program in a college. The idea is to present the prospective employer with not only an academic credential, but also evidence of employable skills.*"[5]

Under Ontario's Post-secondary Education Choice and Excellence Act 2000, Ontario's non-university academic institutes are allowed to offer 4-year bachelor degree programs [12], which are subject to rigorous review process followed by ministerial consent. The Act establishes the composition and authority of the Postsecondary Education Quality Assessment Board (PEQAB). The PEQAB is responsible for reviewing applications for consent and making recommendations to the minister on the quality of programs and organizational soundness [13]. The degrees are granted for number of years (typically, 5 years) and require going through a renewal process, which is similar to first time granting process. More recently universities of Ontario formed Ontario Universities Council on Quality Assurance (in short, The Quality Council) for their undergraduate and graduate program to perform tasks similar to PEQAB tasks.

There are two types of colleges in the province of Ontario [14]: Colleges of Applied Arts and Technology (CAAT) and Institutes of Technology and Advanced Learning (ITAL). The ITAL colleges are leading the way in offering increasing number of 4-year bachelor degree programs (or just degree program, in short) in applied areas of study. Few 2+2 programs (two years in college followed by two years in university) are also available under bilateral university-college agreements [5]. These offerings blur the university-college divide, which was so far a boundary between 3-year and 4-year studies.

B. *Engineering education system and professional associations*

Engineering is a self-regulated profession in Canada. Each of the ten provinces and three territories has engineers association that regulates the practice of engineering and licenses (professional engineer or P.Eng.) individual engineers for legally allowing them to work as engineers [15].

Engineers Canada [15] is the national organization of the provincial and territorial engineers associations. One of its tasks is to accredit undergraduate engineering programs. Engineers Canada does it thorough the Canadian Engineering Accreditation Board (CEAB). CEAB role is similar to what Engineering Accreditation Commission (EAC) of American board of engineering technology (ABET) does. However, CEAB accredits only bachelor degree program [16].

CEAB accredited undergraduate engineering programs provide the education necessary for licensure as a professional engineer in Canada. Accreditation process is also for quality assurance in engineering education and inter-province and international credential mobility [15].

ABET initiated a paradigm shift in engineering education through its Engineering Criteria 2000: Accrediting Programs in Engineering in the United States [17]. It set a world trend of outcome-based curriculum with greater focus on employability skills and societal & environmental care. CEAB adopted outcome-based education model and announced twelve graduate attributes [15] in 2009. These attributes will be used after June 2015 for assessing undergraduate engineering programs. The attributes are:

1. A knowledge base for engineering
2. Problem analysis
3. Investigation
4. Design
5. Use of engineering tools
6. Individual and team work
7. Communication skills
8. Professionalism
9. Impact of engineering on society and the environment
10. Ethics and equity
11. Economics and project management
12. Life-long learning

For the purpose of discussion the author divides the graduate attributes into two categories: core engineering skills or hard skill (1 to 5), and generic employability or soft skills (6 to 12).

Undergraduate engineering programs in Canada are mainly lecture based. Some courses have lab components. Many labs are simulation based. Class sizes are often large to very large (over 75 to over 125). Contact hour and communication between faculty members with individual students is low. Courses are theory focused. Jamison et al [18] presented three approaches in engineering education: scientific, entrepreneurial and ecological depending on their core fuci – science, market and society respectively. Current state of Canadian engineering education falls into scientific category, which is the oldest among these three approaches. However, CEAB initiative is shifting the engineering education paradigm from scientific to entrepreneurial category, which develops ‘job-ready’ graduates. The ecological category appears to be a bit futuristic.

Engineering degrees were offered solely by public universities until recently when some of the public colleges were granted offering undergraduate engineering program. The college engineering programs require going through the approval as well as periodic renewal processes - one from ministry of provincial government through PEQAB and another from Engineers Canada through CEAB.

IV. ANALYSIS OF EDUCATION-JOB MISMATCH IN CANADA

A. *How to respond to increasing globalization and mobility*

Like most of the other countries in the world Canada is affected by increasing globalization. It is beneficial for individual engineers to have awareness of global job market and to actively search for more rewarding opportunities. Question is: is this type of global awareness beneficial for filling gaps in Canadian job market? In author’s view, it is not. While an individual home-grown engineer might be happy to earn more abroad it is the country who will suffer from poor return on investment in education. A counter argument may claim that a reverse trend will compensate this ‘brain-drain’. Author consider it a remote possibility due to the facts that Canada has to compete with other developed countries, which are also in the same predicament [5], and its high tax, strict regulations and visa restrictions may be at its disadvantage. Retention of ‘home-grown’ engineers for local job-market’ is probably an effective way to fight against this problem.

Inter-regional mobility within the country is like a double-edged sword from author’s viewpoint. Too much mobility may move people to booming high-pay area hindering local development due to shortage of skilled people. Too little mobility may cause excess of skilled people in one area and shortage in somewhere else. Following example may clarify this point: a reputed university attracts international students and students far outside of its usual catchment area. On the one hand, these students are more mobile and more likely to leave the region, province or country. On the other hand, some of the local students, who have desire and qualification to get the education in those universities, cannot succeed in the competition. Some of them couldn't afford to study somewhere far from home due to additional expenses, and end up studying something that is not very promising in job market but locally available for them. One remedy of this problem is another engineering program that target local people for local job-market.

To adapt with increasing globalization Canadian businesses need to be globally competitive. One aspect of competitiveness is high productivity and low payroll cost. A job-ready graduate is likely to be more productive. Business community may play active role in shaping the education system so that it can serve them better. Alternatively, they may decide to shift businesses offshore. It is beneficial for the country if education institutes make partnerships with business community for producing graduates that meet the market needs better.

B. Employable skill and practical hard skill developemt

Job market demands 'practical' engineering graduates. Multi-disciplinary design skill is in demand for SMEs as they can't afford hiring large number of engineers – each with different skills in order to cover all relevant areas.

Implementation of graduate attributes is seen as a very vital step forward for producing job-ready graduates. Question is how are the universities, which are the sole institutes until recently for producing engineering graduate, are doing with it? In author's view, the first two (knowledge-base and problem-analysis) of the twelve attributes are well-covered in traditional approach. Third, fourth and fifth (investigation, design and engineering tools) are covered sparsely in first three years and little bit more in 4th year under 'capstone project'. Other attributes may exist in some courses but not adequate, especially in term how they are evaluated after delivery.

Some of the programs have a number of paid work terms (co-operative education), which are apparently the main avenue for the students to be practical and to acquire employability skills. A notable example is University of Waterloo. Only few universities practice project-based curriculum. A notable example is University of Sherbrook. Some universities are playing leading role in researching and deploying innovative modern curriculum design and delivery, especially in implementing the CEAB graduate attributes. Notable example is Queens University. Yet another example of initiative to implement graduate attribute is Engineering Graduate Attribute Development (EGAD) project [19]. This project is co-sponsored by the National Council of Deans of Engineering and Applied Science (NCDEAS) and Engineers Canada. EGAD offers recommendations to Canadian faculties and schools of engineering on outcome-based programming, assessment, and accreditation. These universities take initiative to embrace entrepreneurial aspect in their engineering programs.

However, implementation of graduate attributes is yet to show results as it was evident from the engineering student survey [21], which shows that the last seven graduate attributes, as listed above, are the top seven attributes that are least effectively mastered by the students. In author's view, these universities have two big challenges in implementing soft-skill related graduate attributes. First one is the challenge of transition from heavily science-focused engineering to entrepreneurial engineering. This transition requires strong motivation and support from faculty members who as a team will make this transition happen. It is interesting to see how much interest faculty members will have to make this transition, when many of them are very successful in discipline specific academic researchers, fond of scientific engineering, have tenure and enjoy academic freedom. Author doesn't see many elements that could inspire them to drive the change especially when it requires a considerable effort to redesign the courses and adopt appropriate teaching strategies. Second is the challenge of having sufficient teacher-student contact hour in order to practice and evaluate these attributes. Many universities are research focused institutes, and the cost of research is affordable when the class size is sufficiently large [5].

There are two effective tools in place to address this: cooperative-education (education with work-term) and project-based learning. The cooperative education gives students real work experience, where they acquire practical skills as well as employability skills. Only a small fraction of engineering programs have mandatory co-operative education option. The co-operative education, however, gives different students different vertical (technical level of the job) and horizontal (breadth and diversity of fields) experience. Assessment of the quality of knowledge and skills as acquired in work-term is difficult to rank. Second tool, the project-based learning, simulates workplace environment and authentic real-world projects, and challenges students to practice graduate attributes. Since the project definition and evaluation are under the control of the faculty-team it is likely to give them opportunity to deliver and evaluate graduate attributes better. However, designing and delivering such a project is a difficult and complex task.

C. Balance between two extremes – education for broader knowledge-base and training for specific job

Education for job-ready graduate demands more practice of soft skills and also practical hard skills. It generally reduces available amount of time for theoretical learning, which gives student the foundation for life-long learning. Question is where is the balance? The following example may clarify this point. Cellular mobile technology is rapidly evolving. Question is how to teach such a course? Will we teach the basic technologies behind most of the contemporary and future commercial systems, or we teach specific contemporary and emerging commercial systems? First approach builds students' ability to learn any commercial system but it requires further time to learn. Second approach develops knowledge and skills that have demand in current job market. However, the students are expected to be weaker in theoretical foundation, which may be a disadvantage for learning new emerging systems and technologies. This example highlights the necessity of balancing between generic and specific. The current engineering education appears to follow the first approach.

D. Where is the gap

A niche market demands for 'practical job-ready' graduates and expects that these graduates will serve them long enough to justify return on investment such as cost of recruitment & training and also indirect cost of lost time until a new recruitment is up to speed. Current education system so far couldn't keep up with the market demand. Simply put, the job market wouldn't see this gap in the first place if the current system be able to deliver.

Universities are predominantly producing scientific engineers. Canada needs scientific engineers in order keep itself competitive in research and innovation. Some of the research universities such as U-15 (a group of 15 research universities) must keep their focus on producing engineers for research and innovations. At the same time, the country needs entrepreneurial and practical engineers for high productivity in engineering sector. Question is: can a university produce both types of graduates? It is difficult to do so. More pragmatic way is institutional separation – research universities for producing research engineers and others for producing entrepreneurial and practical engineers. Research-focused universities may not be able to properly embrace this type of education, and they shouldn't do it either. Reference [5] supported the idea of regional universities for focusing on job-ready graduates, and 8 to 10 top-notch research-universities for scientific engineering graduates. Canadian public colleges are in general more market-focused and practical than the universities. In producing practical job-ready engineers, college engineering appears to be a good fit.

E. Effect of paradigm shift

CEAB initiated the paradigm shift in undergraduate engineering education through its announcement of outcome-based graduate attributes and permission for undergraduate engineering degree programs at public colleges. Question is how the paradigm shift will impact on education-job mismatch? Implementation of graduate attribute is expected to significantly improve the gap in employability skills. By allowing college engineering the CEAB opened a new path of producing 'practical' engineers who are educated for job as opposed to higher education. These programs take advantage of college setting to produce job-ready graduates.

V. How to Fill the gap: a Case Study

Since 2004 Conestoga college ITAL, a leading Canadian college, has been offering project-based four-year Bachelor degree program in integrated telecom and computer technologies (ITCT). From September 2014 this program became an accredited engineering program with new name Electronic Systems Engineering (ESE).

This program is mandated to meet all the requirements set by PEQAB for a bachelor degree program as well as all the requirements set by CEAB for an accredited undergraduate engineering program. This program keeps focus of applied learning for niche job market, which is a 'college specialty', through its cooperative education and project-based learning approach for its curriculum delivery.

A. Curriculum development and delivery models of the program

From the beginning this program envisioned for industry-desired job-ready graduate. As an accredited engineering program this program is set to produce job-ready engineers for the niche job market.

Its curriculum design & delivery models, and observed success and challenges were reported in author's previous paper [20]. Some of the key aspects are stated below.

Through its PAC (program advisory committee) the program regularly gets updates on job market demand, emerging technologies & products and regulations & standards. These inputs together with faculty members' own studies guide the curriculum update for next cycle of delivery. The program applies team approach in developing curriculum and projects and their continuous improvements.

The pedagogical strategy of project-based learning has the following three characteristics:

1. Learning is driven by challenging open-ended problems.
2. Students work in small collaborative groups.
3. Teachers take on the role of "facilitators" of learning.

All three of these characteristics resemble a real-world engineering environment where problems are fairly open-ended, engineers work in teams, and a team-leader or manager facilitates the process.

This is a project-based learning program. Each semester has one or more educational project themed with courses taught in that semester. Projects are electronic system development projects that have practical applications and require multidisciplinary knowledge. Projects in higher semesters are more open-ended and offer higher design challenges.

Each cohort of students has a 'homeroom' of up to 30 students. Each student has a dedicated workbench equipped with a computer and a full set of bench equipment for electronic prototyping and measurements. The centre of each homeroom is a lecture theatre. This dedicated space resembles an engineering workplace where each staff member has his/her own cubicle and there is a central conference/meeting room. The school day emulates a workday where students spend about six hours in scheduled class activities and a few more hours working on their projects. The setting and schedule maximize student-student interaction. Since students spend most of their workday together, they are encouraged and willingly share their expertise with other students, boosting peer support and teamwork skills. Homerooms for each class are located in the same hallway. This encourages cohort-cohort interaction both academically and socially.

B. How is the program helping reducing the gap

This program was designed to meet niche market demand: appropriate field of study, practical skills, system design skills, and generic employability skills. The college is located in the heart of Canada's technology triangle, the home of many hi-tech electronics industries, including well-known Blackberry cell-phone manufacturer. This program was a result of extensive consultation with industry partners.

Cooperative education, project-based learning approach, small class size, and workplace environment in the class room help achieve three objectives: graduates with practical skills, multidisciplinary design skills and employability skills (generic soft-skills).

The program has industry sponsored applied research program for commercialization of research outcome. Some of the faculty members and students are actively involved in these projects. This is a venue through which the program contributing to business development.

C. Continuous improvement and quality assurance

One of the main goals of engineering accreditation is quality assurance of the engineering education. This program has auditable process of quality assurance and continuous improvement. Besides the comprehensive outcome-based course outline with course outcomes and session outcomes, the program has the following processes in place.

- Mapping between course-outcomes and CEAB graduate attributes.
- Collection of academic evidence after delivering a course. This is a collection of faculty members' course materials and samples of students' works, such as examination, quiz, lab, project, home-work, presentation and in-class assignments.
- Continuous improvement form, which is a report from a faculty member on the delivered course. This report indicates any deviations from what was proposed in the course-outline and the mapping sheet. This report also proposes changes to improve the course and projects for future delivery.
- Team review of course outlines, mapping sheets and also projects for next cycle of delivery.

VI. Conclusion

Canadian education-job mismatch can be reduced by producing practical entrepreneurial engineering graduate in parallel to scientific engineering graduates that the current education system is producing. In author's view, it is a difficult task for research-focus universities to produce both types of graduates. Instead, it requires institutional separation – research universities for producing scientific/research engineers and others for producing entrepreneurial/ practical engineers. The case-study presented an example of programs that has high potential of producing entrepreneurial/ practical engineers in order to meet the requirements of niche job market and hence reduce the education-job mismatch.

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