Engineers Without Borders In-Canada Engineering Educational Programming – Case Study of Two Projects

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Abstract – *The 21st century brings a number of opportunities and challenges that require the innovative capacity of the engineering profession. Many of these challenges and opportunities are shaped by globalization, which has impacts on how the engineering profession is educated and ultimately practices. Engineers Without Borders Canada (EWB) has recently completed the development of two projects that enable engineering students to develop skills for engineering practice in a globalized world. These projects are based on ‘complementary learning outcomes’-areas that complement CEAB outcomes while providing a 21st century perspective.*

The first project is a final year technical elective focused on enabling electrical engineering students to combine the skills they have learned in other courses with complementary 21st included the application of systems thinking to engineering problems, sustainability and its relation to electrical engineering, and globalization and its impacts on engineering practice. The outcome of this course is to expand their ability to practice in a globalized world. EWB’s second program is a certificate that is aimed at recognizing students who develop 21st century skills throughout their education through curricular and co-curricular engagement. For curricular measurement, the certificate offers a framework to determine which courses enable the development of 21st century skills. The co-curricular component applies best practices for leadership evaluation from a number of institutions worldwide to effectively measure a student’s leadership experiences. The certificate both serves to encourage students to explore unique educational and leadership opportunities while also to recognize students who have invested their time in developing 21st century skills.

Keywords: 21st century engineering, curriculum evaluation, interdisciplinary, leadership, diversity, innovation, globalization, communication, project management, certificate, program

1. INTRODUCTION

The engineering challenges of the 21st century have created the need for significant changes in both the content of engineering curriculum and the methods by which they are taught. Engineers play many major roles in society as decision makers, influencers, and conveners, and therefore there is an impetus to complement the traditional technical curriculum with new 21st century knowledge and skills.

Engineers Without Borders (EWB) Canada defines global engineers as engineers that are equipped to lead within their communities and the profession in the 21st century. Global Engineering is EWB’s collaborative program to encourage and support the development of a new generation of engineering graduates who are ready to practice in a globalized 21st century environment. These graduates have taken part in innovative educational experiences that have tempered their leadership skills, expanded their problem solving ability, and developed a global awareness that, along with their engineering technical excellence, will enable them to go beyond engineering and play a leading role in Canada and on the world stage in the 21st Century. In particular, EWB’s vision for global engineering is grounded in four principles:

- Awareness of globalization and its impact on engineering practice,
- Capability of practicing leadership and interdisciplinary skills,
- Competency in exploring the engineering profession’s role in complex societal issues and,
- Ability to apply technical skills in a global context

EWB’s work with university faculty in engineering curriculum has given EWB an appreciation of the strengths of engineering faculties in addition to the needs of students to practice engineering in a globalized 21st century environment. This paper outlines the background research and experiences that informed the development of EWB’s two key

projects; a technical elective course, and a certificate program. The certificate program has been created with the intent of flexibility and adaptability to be applied to educational institutions across Canada. The paper will provide the outline and key learning outcomes of both these projects. These projects are both a small piece of EWB's theory of change for engineering curriculum. The nexus of key stakeholders and the development of strong partnerships with faculty members has been a key component of the success of EWB's projects which will further enable EWB and partners to achieve a broader change in the delivery and the demand for engineering education.

2.BACKGROUND RESEACH AND EXPERIENCE

2.1 Background Research

During the development of the two EWB projects, background research was conducted on engineering curriculum both in Canada and internationally. ¹Universities were evaluated based on their alignment with 21st century engineering practices. Each institution was ranked based on criteria deemed important to global engineering and engineering practice in the 21st century. These include overall vision and direction of the engineering faculty, topics relating to engineering and society, opportunities for interdisciplinary learning and project work, programs and recognition for leadership growth, diversity of research including topics connecting technical engineering to society, innovation in the engineering curriculum, topics relating technical advancement and globalization, an emphasis on communication and project management including cross cultural communication, and opportunities for work experience that directly connects to an overall curriculum design. [1] This research supported the structure of both the technical elective course and the certificate program.

A component of the research was focused on an additional audit of co-curricular programs at institutions both in Canada and abroad. The findings of this research were used to develop the evaluation framework and the structure of the extracurricular component of the certificate program.

¹ The analysis of this research can be found in the CEEA 2014 conference paper titled "Comparative Analysis of Engineering Curricula for Alignment with 21st Century Engineering Practices"

2.2 Experience

Working with faculty across Canada, EWB has built an appreciation of the strengths of traditional curriculum to enable students to solve global challenges. Through numerous surveys EWB has identified a gap in the learning outcomes of students. Students typically emerged from courses with complementary 21st century skills due to personal interest rather than opportunity created through the institution. Due to this gap, the certificate program is designed to provide student who have an interest in understanding the globalized context of engineering with a method to formalize and recognize their additional competencies and further develop them.

3. COURSE DEVELOPMENT

This section of the paper outlines the first EWB project that was conducted. This project is a final year technical elective that was developed by EWB for electrical engineering students. The focus of this course is on enabling electrical engineering students to combine the skills they have learned in other courses with complementary 21st century skills and mindset. The course included the application of systems thinking to engineering problems, sustainability and its relation to electrical engineering, and globalization and its impacts on engineering practice. Case studies were included in the course to provide students with a practical context of application of 21st century skills. These included:

- Electrical engineering design and practice in low and middle income areas of the world,
- System level design to choose appropriate technology, and resolve technical electrical engineering issues in a foreign context and,
- Various fields of electrical engineering in global development discussed with a specific focus on lighting and power systems in developing countries.

3.1 Learning Outcomes

The learning outcomes of this course were designed by combining technical skills with the global engineering principles. The outcomes are listed below:

- Gain a better insight about the role of electrical engineers in global systems
- Understand the impact of poverty and access to credit on technology deployment
- See development as a complex system, and understand the use of leverage points for achieving objectives
- Improve systems and device level design with considerations for localized context

- Understand the units and quality of lighting.
- Understand how lighting technology works, and how to design small-scale lighting systems
- Understand how to choose and evaluate lighting systems based on local needs by using life cycle costing as a tool
- How to integrate uninterruptible power supplies to achieve target reliability in unreliable grids
- Design energy generation mixes and size energy storage for micro grids
- Understand how electricity policy affects people, specifically metering policy

3.2 Course Evaluation

The course was evaluated based on a combination of quizzes, assignments, and a final exam. Assignment topics were focused on:

- Global Engineering and systems sciences
- Lighting Systems design and costing
- Energy Systems for developing countries

In order to integrate the global engineering principles, the course include two open-ended projects that require critical thought and analysis to reach conclusions. With a report and presentation as final deliverables, students were presented with the opportunity to integrate both their technical skills and 21st century skills.

4. CERTIFICATE PROGRAM

This section of the paper outlines the certificate program that EWB has developed in collaboration with University of Calgary faculty. The certificate program integrates the final year technical elective (previously discussed) as a component of the certificate requirements. The certificate recognizes and promotes Global Engineering education and practice. EWB in partnership with the Schulich School of Engineering (SSE) at the University of Calgary will offer a course/curriculum and leadership based certificate to promote Global Engineering practice and education for the globalized 21st century.

4.1 Certificate Goals

The goals of this certificate are aligned with EWB's experience working on global engineering education as well as the university priorities of leadership and engineering for the real world. EWB has collaborated with students and faculty at the SSE for over five years in the development of Global Engineering

education. These collaborations have included the development of assignments, lectures, exams and evaluation tools, and an entire course dedicated to Global Engineering practice. This certificate is the natural next step from a strong history of collaboration and will enable the development of Global Engineers at the SSE.

The certificate is intended to recognize the learning and development of students that enable them to lead as engineers. Specifically this certificate will:

- Create recognition for the value of Global Engineering – both internal to the student community and outside of it
- Promote and incentivize the development of Global Engineers through a streamlined certificate program
- Develop opportunities for continued engagement with Global Engineering education and practice for students, practicing engineers, industry, and faculty

4.2 Key Learning Outcomes

The certificate promotes learning and professional development in students through requirements inside and outside of the classroom. The key learning outcomes that are recognized by the Global Engineering certificate are:

- Awareness of globalization and its impact on engineering practice
- Capability of practicing leadership and interdisciplinary skills
- Competency in exploring complex societal issues
- Ability to apply technical skills in a global context

These learning outcomes have been developed based on the alignment between Global Engineering and engineering education programs.

4.3 Certificate Requirements

The certificate requires individuals seeking to be awarded the Engineers Without Borders Global Engineering Certificate to be registered in a CEAB accredited engineering program. These individuals must pursue a blend of classroom and out of classroom learning throughout their educational

experience. The certificate requires successful completion of the following components:

1. Global Engineering Education (Course Work)
2. Global Engineering Practice (Extracurricular Activities)

4.3.1 Global Engineering Education (Course Work)

The education component of the certificate recognizes knowledge developed that is strongly tied to the vision of Global Engineering. Individuals wishing to be awarded the Engineers Without Borders Canada Certificate in Global Engineering must demonstrate they have completed three courses that cover three essential Global Engineering education topics.). These courses are:

1. Introduction to Global Engineering and core Global Engineering Concepts

An online introductory course focusing on what it means to be practice global engineering in the 21st Century. The first part of the course provides the context and current impacts of globalization on society specifically targeting the application of appropriate technologies, facilitated by EWB. The second part will focus on the relation of globalization to the global engineer with an introduction into theories of change and systemic innovations delivered by a speaker series. Significant emphasis will be placed on social, environmental and economic consequences of engineering on society globally.

The course will be delivered through a series of online guest lecturers from experts internationally over the course of the semester with one lecturer per week. This course will be administered by EWB. Further dialogue is needed on whether this course will count for degree credit or will be separate.

2. Discipline Specific Global Engineering Practice

Global Engineering for “Discipline”(electrical/civil/chemical/mechanical/geomatics/oil&gas/software) Engineers is designed to build upon the introductory course with discipline specific concepts and ideas. This course will provide frameworks, techniques, and knowledge that enables Global Engineers to approach “discipline” specific

engineering problems practice in a globalized world as well as in low and middle income areas of the world. By the end of this class, the student will be in a better position to approach system level design to choose appropriate technology, and resolve technical “discipline” engineering issues in a globalized context.

3. Interdisciplinary Project Based Learning

An interdisciplinary team project involving the application of engineering principles, design, and project management concepts; the theory, experience and practice of project management (including generally accepted project management principles, team management and conflict resolution, the structure of both project and team, together with ancillary topics that commonly affect project outcome); review of Global Engineering projects, including EWB’s work in Africa.

These course requirements may be a unique Global Engineering course, or may be filled by existing courses that are aligned with the Global Engineering vision. EWB, in consultation with the host institution, must approve in advance the set of courses that are proposed to meet the course requirements for the Global Engineering Certificate. The courses that are accepted as part of the certificate will be reviewed annually in order to ensure that students have a full breadth of options that lead to the certificate.

4.3.2 Global Engineering Practice (Extracurricular Activities)

In order to augment the skills student learn through course components of the certificate, registered involvement in extracurricular activities that contribute to the student’s broader development as a Global Engineer is also a critical requirement of the certificate. Through these activities students will gain opportunities to enhance their leadership, teamwork, and communications skills.

This portion of the certificate has three different streams of implementation that can be used. The flexibility of these streams allows the institution to select the most appropriate stream that meets student demand.

<u>Option A</u>	<u>Option B</u>	<u>Option C</u>
1. Leadership Experience in nonprofit, government, or industry - <i>120 hours</i>	1. Leadership Role on campus that applies learning outcomes from courses included in the certificate – <i>120 hours</i>	1. Requirements of Option A OR Option B (Modified)
2. Experiential Leadership through short-term involvement in leadership training – <i>20 hours</i>	2. Engineering Practice on a real world engineering project – <i>70 hours</i>	2. Share Experience via Interactive Learning Session
3. Volunteer Experience OR Study/Research Experience Abroad – <i>120 hours</i>	3. Experiential Leadership through short-term involvement in leadership training – <i>120 hours</i>	3. Mentorship of protégé entering the program
<u>Evaluation</u>	<u>Evaluation</u>	<u>Evaluation</u>
Feedback from peer / supervisor + reference letter	Reference letter for each involvement	All evaluation requirements of A or B
Leadership Portfolio	Personal Development Plan	Written summary of the session
Final presentation to other candidates	Capstone Project	Letter from the protégé

The structure of this program is designed to target the core competencies of a leader as described below. These competencies were a result if EWB's research previously discussed.

Competency	Description
Commitment	<ul style="list-style-type: none"> having the energy, ability, and determination to serve a group and its goals
Congruence	<ul style="list-style-type: none"> understanding the connection between own values and those of the group
Emotional Intelligence	<ul style="list-style-type: none"> being self-aware of the values, attitudes, and beliefs that motivates him/her to act and commit
Collaboration	<ul style="list-style-type: none"> working with others towards a common goal while sharing responsibility, accountability, and knowledge having the ability to increase group effectiveness by capitalizing on and nurturing various perspectives, viewpoints, and talents, and using these various perspectives, viewpoints, and talents to the benefit of the group as a whole
Common Purpose	<ul style="list-style-type: none"> re evaluating and adjusting strategy and goals based on the changing needs of the individual/group
Community	<ul style="list-style-type: none"> having the ability to recognize the systemic lens of contributions to the group/organization on a local to international level
Change	<ul style="list-style-type: none"> demonstrating the importance of making a better society and world for oneself and others demonstrating individuals and communities are capable of working together to create change

5. RESULTS AND DISCUSSION

Within EWB, the ultimate goal is to contribute to an engineering education system where every engineering student graduates ready to contribute to complex challenges locally and globally. EWB's theory of change is focused on three mechanisms in temporal order:

- Triggering a change in delivery of engineering education through specific curriculum structure mechanisms
- Triggering a change in the demand for type engineering education and graduate through the provision of a tipping point population of graduate
- Triggering an overall change in the engineering education and practice space

The projects outlined in this paper are a subset of EWB's first mechanism for change in the engineering education system.

The technical elective has yielded strong positive results. With registration on the rise, there was an indication of student demand for these opportunities to be integrated within the traditional classroom.

Beyond the classroom, the certificate seeks to expand and innovate on the method of delivery of traditional curriculum. The richness in learning within a student environment is partially attributed to the diversity of material and also the audience. The certificate capitalizes on this by utilizing an online platform to connect students across the nation. With interest from various institutions in a certificate, the online platform creates the opportunity for student to connect across Canada and abroad on the "Introduction to Global Engineering and core Global Engineering concepts" course. The trend in e-courses can be leveraged to create an online learning platform through a host university to disseminate engineering education that is unique compared to what other institutions offer - changing the way Canadian, and possibly international, engineers engage with these concepts.

The flexibility of the certificate allows institutions to adopt similar structures while maintaining integral components of their institution's identity and still achieving the learning outcomes that support the students to practice engineering in the 21st century.

6. CONCLUSIONS

The engineering challenges of the 21st century have created the need for significant changes in both the content of engineering curriculum and the methods by which they are taught. Engineers play many major roles in society as decision makers, influencers, and conveners, and therefore there is an impetus to complement the traditional technical curriculum with new 21st century knowledge and skills.

The current engineering education system is changing – new CEAB requirements, advocate professors and deans, and organizations like EWB are actively contributing to a paradigm shift within engineering schools. The integration of the final year electrical engineering technical elective within the engineering education system signifies the changes that are happening. The development of the certificate with increasing national support is a demonstration of the changes that are upcoming in the engineering education system. Through stronger partnerships and the certificate program is being fostered for further growth in order to support the changes that EWB and others are working to achieve.

7. REFERENCES

[1]	J. Fishbein, "The Global Engineering: An Implementation of Outcomes-Based Accreditation Requirements," <i>Proceedings of the Canadian Engineering Association</i> , p. 6, 2011.

8. ACKNOWLEDGMENTS

- University of Calgary faculty
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