DEVELOPING ROLE MODELS FOR ENGINEERING AND SUSTAINABLE DEVELOPMENT: ENGINEERS WITHOUT BORDERS' GLOBAL ENGINEERING CERTIFICATE

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Abstract: The presence of role models within the engineering community has long been an integral component of the education and cultivation of successive generations of the profession. As the profession continues to grow and evolve, new types of role models are required to reflect the changing nature of the world within which the profession exists. One such evolution is the creation of Global Engineers, professionals who are competent in an increasingly complex and globalized society. In this paper, we explore the function of role models in creating shifts within the profession in past decades and discuss the Global Engineering Certificate being implemented by Engineers Without Borders Canada at several Canadian universities to help develop role models within the Global Engineering space.

1. INTRODUCTION

Globalization has been a widely discussed and debated topic since the dawn of the millennium. The increasingly rapid movement of people, ideas, goods and capital has its advantages but has also led to an exacerbated disparity between the rich and the poor (Shangquan, G, 2000). Engineers that consider economic, environmental and societal aspects at work must be aware of globalization and how it factors into their work.

Due to the trends of globalization, the changing role of engineers in society, and the broad-scale changes in secondary education, Engineers Without Borders Canada (EWB) believes that more Global Engineers are needed to tackle the complex problems of the 21st century. EWB defines Global Engineers as those who have the following knowledge, skills and attributes:

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

EWB believes that increasing the number and visibility of Global Engineer role models is an important step to foster the development of future Global Engineers. Within the Canadian context, role models play a key role in the engineering community. This paper explores examples of how role modelling has been used within engineering to increase the number and visibility of women, aboriginal peoples and environmentally sustainable design engineers. We discuss (1) why EWB believes that role modelling is key to increasing the number of Global Engineers graduating from accredited Canadian engineering institutions, (2) EWB's strategy to increase the number and visibility of Global Engineer role models, and

(3) how EWB's Global Engineering Certificate Program is structured to support the creation of more Global Engineer role models.

2. CASE STUDIES: ROLE MODELS IN ENGINEERING

In this section, we explore the key functions that role models played in changing the Canadian engineering profession in response to emergent issues. In this work, the case studies we examine include women in engineering, Aboriginal students in engineering, and environmentally sustainable design. We show that role modeling was key to increasing the representation of these sub-groups within engineering and that role modeling will therefore play a key role in increasing the visibility and number of engineers who demonstrate the characteristics of Global Engineers.

2.1 Women in Engineering

Engineering has traditionally been a male-dominated profession and community in Canada. The question of how to engage more women in the profession has been a perennial issue raised at all levels. From 1999 to 2013, female enrollment into Canadian engineering programs has decreased from 20.6% to 18.9% (Engineers Canada, 2014). Further, the proportion of engineering students who transfer programs and the proportion of engineers who change professions is higher for females than males (Fouad, 2014). This attrition is often attributed to the engineering culture that perpetuates stereotypical male behaviour within student communities and a limited perception of prospects for women upon entry into the professional community (Fouad, 2014). The percentage of women in high influence positions in the engineering education community remains low with an average of 9% of tenured professors being women across Canada in 2013 (Engineers Canada, 2014).

As an aspect of one's identity with a socially visible component, female engineers can very easily become role models to trigger more women joining and staying in engineering simply by their presence within the engineering community. In a study examining the performance of a cohort of chemical engineering students, a lack of women role models was identified by the investigators as a source of steadily declining performance among female students compared to their male counterparts (Felder et al., 1995). Within academia, mentorship relationships are more likely to be successful when the mentors reflect characteristics and traits that the mentee can empathize with (Chesler and Chesler, 2002). Sonnert et al. (2007) further found that the more relatable role models are to the desired path of women engineering students, the greater influence this has on academic performance and graduation rates.

Efforts to address the challenge of insufficient role models for women in engineering have largely focused on addressing this role model deficit by shining a light on women within the engineering profession through awards and recognition in publications from professional associations and universities. In addition, numerous committees and organizations across the country advocate for ongoing efforts to find new and better ways to recruit women to study engineering. These organizations undertake interventions during adolescence, challenging the dominant engineering culture, and hosting spaces for these issues to be discussed and explored. Several examples include the National Conference on Women in Engineering, Engineers Canada's Women in Engineering Committee, and the Women in Scholarship, Engineering, Science and Technology organization based at the University of Alberta.

2.2 Aboriginal Students in Engineering

Another population that is disproportionately underrepresented within the engineering community is Aboriginal students and professionals. The Aboriginal community in Canada is growing faster than the non-Aboriginal population, yet enrollment within engineering schools remains low (Statistics Canada, 2011). This underrepresentation within the engineering community is often attributed to disconnects between traditional ways of knowing and contemporary science, and socio-economic barriers to Aboriginal students accessing higher education (Canadian Council on Learning, 2007). But the lack of visibility of successful Aboriginal role models within the engineering profession also plays a significant role in limiting the perceived opportunities that Aboriginal students see as available to them.

As noted above with respect to women in engineering, the closer that an individual is able to empathize with a mentor the greater of an impact that mentor will be able to have in increasing the perceived opportunities of their mentee (Lockwood, 2006, Gibson, 2004). In the case of Aboriginal representation within the profession, Aboriginality is not always a visibly identifiable component of one's identity. As such, efforts to connect prospective students with professionals requires established programs such as that initiated by the Association of Professional Engineers and Geoscientists of Alberta (APEGA) in Alberta which connects professional mentors with students in five high schools in Edmonton and Calgary with high Aboriginal student populations (Littlechild, 2012). The Canadian Council of Professional Engineers has made efforts to connect Aboriginal students to Aboriginal engineers through their outreach and education programs, including an online platform highlighting "A Day in the Life of an Engineer" (Pleasant-Jetté and Wiseman, 2006).

2.3 Environmental Sustainable Design

As the importance of environmental sustainability has grown in increasing importance within engineering, new ways to teach and engage engineering students about their role in practicing sustainable work has also become increasingly important (as evidenced by the existence of the conference at which this paper was presented, the International Conference on Engineering Education for Sustainable Development). Integration of sustainability concepts into the engineering curriculum has become integral to the accreditation of undergraduate degrees in Canada.

Unlike women or Aboriginal representation in the engineering profession, role modeling excellence in environmental sustainability is a much less visibly identifiable characteristic of a role models identity. Within practicing engineering communities, the Leadership in Energy and Environmental Design (LEED) program is an example of a third party validation of sustainable design which can be used as an example for others to follow from. This is limited in that it focuses particularly on building construction and design which makes it particular to one discipline. Similar programs such as Environmental Professional accreditation typically focus on those disciplines or practice areas that have a clear connection to environmental sustainability and do not always encompass areas which have less tangible relationships to environmental sustainability. In our increasingly interconnected and complex world systems, drawing attention to sustainability is important in all aspects of engineering practice and the skills of systems thinking and complexity analysis are integral to a comprehensive engineering education.

3. EWB'S THEORY OF CHANGE

EWB's organizational mission seeks to accelerate systemic innovations in Canada and Africa that have the potential to disrupt systems that allow poverty to persist. Engineers, as part of this global system have the ability to create positive change in all aspects of their work. In order to tackle the complex problems of the 21st century, engineers need to be equipped with the right skill set to interact in the globalized world, a skill set we define as those of the Global Engineer.

3.1 Why Role Models?

Engineering training is built on a foundation of role models from our professors at school, to professional mentors that teach us how to perform the act of engineering with integrity and effectiveness. Our professional institutions require that new engineers, those who are still "in-training", have their work overseen by a seasoned professional who is wise in the ways of their practice. This model has served our profession well in terms of training technically proficient engineers.

As discussed earlier in this paper, role models have been used within the engineering profession to increase the number of women, Aboriginal students and environmentally sustainable professionals. This leads to the conclusion that role models are a key component in encouraging development of a specialized type of engineer. In order for the engineering profession to evolve and tackle the complex problems of the 21 century, Global Engineer role models will be key in inspiring the development of more Global Engineers.

3.2 Why a Certificate Program?

EWB theorizes that the Global Engineering Certificate program will streamline the path that a student needs to take in order to gain skills as a Global Engineer. We believe its effects will include (1) highlighting current Global Engineers as role models, (2) inspiring more engineering students to gain the knowledge, skills and attitudes of a Global Engineer and (3) making clear the path that a student needs to follow in order to gain the knowledge, skills and attitudes of a Global Engineer.

4. CERTIFICATE DESIGN

The Global Engineering certificate contains two main components, the first being theoretical (three half-course equivalents) and second, practical (120 hours of co and/or extra-curricular activity). The aim of having both of these experiences is to ensure the students are able to not only learn Global Engineering theory but also have experience in applying Global Engineering concepts and apply them in a real-world situation. As the practice of Global Engineering is about dealing with complex problems of the 21st century, it will be vital for students to experience the challenges that are coupled with creating and implementing a solution to complex and ambiguous problems.

While the certificate program offers EWB a mechanism to validate a level of global education for the certificate recipients, an integral component of our theory of change relates to other students wanting to emulate these role models and pushing the limits of their own education.

4.1 Learning Outcomes

The learning outcomes of the Global Engineering Certificate build off of the 2014 Canadian Engineering Accreditation Board (CEAB) Graduate Attributes (CEAB, 2014): The key learning outcomes of the Global Engineering Certificate are as follows:

1. Aware of globalization and its impact on engineering practice
2. Aware of globalization and its impact on engineering practice
3. Capable of practicing leadership roles and interdisciplinary work environments
4. Competent in exploring complex societal issues
5. Able to apply technical skills in a global context

4.2 Theoretical Component

Three courses are required under the theoretical component of the Global Engineering Certificate: (1) Introduction to Global Engineering Course, (2) Discipline-Specific Global Engineering Course and (3) Interdisciplinary, Project-based Course. The courses have been selected in order to fit into a student's graduation requirements from their home university meaning that enrollment in the Global Engineering Certificate does not necessitate an increased course load. In order to fulfill the Global Engineering Certificate requirements, the student must successfully pass the courses in question. Approval of a course's ability to meet the stated learning objectives will be lead by EWB.

4.2.1 Introduction to Global Engineering Course

The Introduction to Global Engineering Course is meant to be the first formal interaction that students have with Global Engineering concepts when they enroll in the certificate. The Introduction to Global Engineering course content will be reviewed by EWB to ensure that the learning outcomes are achieved by said course.

EWB has outlined the following learning outcomes for students who complete the course:

1. Be able to perform critical analysis of engineering practice in a globalized world context,

2. Be able to form opinions on how technology contributes to changes in society and vice versa,
3. Demonstrate knowledge of the historic and present role of engineers in global systems,
4. Possess a functional understanding of globalization and development as complex systems,
5. Understand the role of engineering in systemic change,
6. Be aware of systemic failures in technical and societal systems,
7. Be able to evaluate and make decisions on technology, policy and processes as leverage points for systemic change.

When the Global Engineering Certificate was launched in fall 2014 at Memorial University of Newfoundland (MUN), the EWB's Online Introduction to Global Engineering course was not available. Students working toward the certificate in 2014/15 were required to fulfill the course component by taking MUN's ENGI 8151: Technology, Sustainable Society and International Development. The ENGI 8151 course offered by MUN was available both in-person and online, the course was also available to students who did not study at MUN. In the future, EWB plans to offer the Introduction to Global Engineering course online. The platform that will host the course will also provide a library of Global Engineering resources in the form of a library and online network of Global Engineering students and professionals.

It is recognized that some Universities might be keen to develop their own, in-person Introduction to Global Engineering Course, in this case, EWB would work with the universities to develop these courses. The development of Introduction to Global Engineering courses by individual universities will show a positive sign that Universities are eager to further pursue the inclusion of Global Engineering concepts in their curriculum.

4.2.2 Discipline-Specific Global Engineering Course

The Discipline-Specific course will cover frameworks, techniques and knowledge that enable Global Engineers to approach discipline-specific system level design in a globalized world as well as in low and middle-income areas of the world. By the end of the 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.

EWB has outlined the following learning outcomes for students who complete the course:

1. Be equipped with a foundation to apply their technical skills in a global context,
2. Develop knowledge of the role of their discipline of engineers in global systems,
3. Understand system level design to develop appropriate engineering projects in a globalized context,
4. Possess competency in exploring complex disciplinary technical problems
5. Have knowledge of appropriate discipline-specific tools for engineering design in different international contexts.

There may be cases where a course has been missed for pre-approval, in this case it will be up to the student to justify how the course they have taken does meet the required learning outcomes of the Discipline-Specific Global Engineering course. This information would be taken into account when EWB publishes the updated list of approved courses for the certificate.

At MUN and the University of Calgary, the first audits revealed that certain disciplines did not have a Discipline-Specific Global Engineering course that could apply to the certificate. In this case, if a University is interested, EWB would work with them to either develop or modify a course to meet the stated learning outcomes.

4.2.3 Interdisciplinary, Project-Based Course

The Interdisciplinary, Project-Based course will require the student to be involved on an interdisciplinary team project involving the application of engineering principles, design and project management concepts.

The following learning outcomes for that students who complete the course:

1. Practice their awareness of globalization and its impact on engineering projects,
2. Demonstrate leadership and interdisciplinary team skills,
3. Practice and apply disciplinary technical skills in a global engineering project,
4. Demonstrate effective communication skills,
5. Develop an understanding the dynamics present within a team, risk management and diagnosing common project problems,
6. Knowledge of Global Engineering Projects and common attributes of successful and unsuccessful projects.

This course will likely be the 4th Year Design Course that is required by the CEAB. All 4th Year Design Courses do not necessarily include an interdisciplinary or global component, in this case students would be required to modify the base requirements of their course in order to meet the learning objectives. Upon completion of the course, the students are required to submit a reflection paper to confirm that they have fulfilled the learning outcomes. Other project courses may be eligible for the certificate, EWB plans to work with each university to determine which courses fall under this category.

4.3 Practical Component

The practical component of the Global Engineering Certificate requires each student to complete 120 hours of experiences that will aid the student in enhancing their leadership, teamwork and communication skills. Within the broader statement of leadership, the student will be asked to develop the core competencies of a leader: commitment, congruence, emotional intelligence, collaboration, common purpose, community and change. These competencies are based on “The Seven C’s: The Critical Values of the Social Change Model” developed by Wagner (2006). These values have also been referenced in a national study performed by the U.S. based, Multi-Institutional Study for Leadership (2007).

EWB has outlined the following learning outcomes for the practical component:

1. Develop leadership skills including: Communication, listening, global collaboration, ethics, willingness to seize new opportunities and the ability to participate in, foster and motivate teams,
2. Demonstrate ability to develop plans and iterate on plans based on identified goals and objectives to foster innovation,
3. Demonstrate ability to monitor and reflect on personal leadership and progress,
4. Deepen understanding and appreciation of the complexity and value found in connections with team members,
5. Participate in building a community for Global Engineering leaders to connect and learn together,
6. Develop the following core competencies of a leader (see above).

These Global Engineering experiences could take the form of leadership roles on and/or off campus, leadership training, engineering practice (via internship, co-op or summer work terms), intensive volunteer, study or research abroad experiences or mentorship of other students enrolled in the Global Engineering Certificate

5. CONCLUSION

In this paper, we discussed why Global Engineers are needed to tackle the complex problems of the 21st century, how role models were instrumental in furthering other sub-groups within engineering (specifically women in engineering, Aboriginal students and environmentally sustainable design professionals), how the Global Engineering Certificate Program can help to fill the role model gap, and how the certificate is structured to develop and promote Global Engineers. By highlighting Global Engineers and filling the role model gap, more students can be inspired to gain the knowledge, skills and attitudes of Global Engineers.

Ongoing monitoring and evaluation is a key part of EWB’s strategy to further develop the theory of change. Close conversation with partner universities and students is required to ensure that the certificate is modified based on lessons learned and well-positioned to create high-quality and high-visibility Global Engineer role models.

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References

- Canadian Council on Learning, 2007. Lessons in Learning: The Cultural Divide in Science Education for Aboriginal Learners. Canadian Council on Learning: Ottawa, ON
- Chesler, N. C., Chesler, M. A. 2002. Gender-Informed Mentoring Strategies for Women Engineering Scholars: On Establishing a Caring Community. *Journal of Engineering Education*, **91**(1): 49-55.
- Dugan, J. & Komives, S. 2007. Developing Leadership Capacity in College Students: Findings from a National Study. <http://mslreviewteam.wiki.usfca.edu/file/view/MSLReport+06.pdf>
- Engineers Canada, 2013. Canadian Engineers for Tomorrow: Trends in Engineering Enrolment and Degrees Awarded 2009-2013. Engineers Canada, Ottawa, ON.
<http://www.engineerscanada.ca/sites/default/files/enrolmentreport2013-en-3.pdf>
- Engineers Canada, 2014. Canadian Engineering Accreditation Board Accreditation Criteria and Procedures. Engineers Canada, Ottawa, ON.
http://www.engineerscanada.ca/sites/default/files/2014_accreditation_criteria_and_procedures_v06.pdf
- Felder, R. M., Felder, G. N., Mauney, M., Hamrin, C. E., Dietz, E. J., 1995. A Longitudinal Study of Engineering Student Performance and Retention: Gender Differences in Student Performance and Attitudes. *Journal of Engineering Education*, **84**(2): 151-163.
- Fouad, N. A. 2014. Leaning In, But Getting Pushed Back (and Out). American Psychological Association 2014 Annual Convention. Washington, DC. August 7-10, 2014.
- Gibson, D. E. 2004. Role Models in Career Development: New Directions for Theory and Research. *Journal of Vocational Behaviour*. **65**(1): 134-156.
- Littlechild, R. 2012. Highlight of Aboriginal Program. APEGA: Edmonton, AB
- Lockwood, P. 2006. "Someone Like Me can be Successful": Do College Students Need Same-Gender Role Models? *Psychology of Women Quarterly*. **30**(1): 36-46.
- Murray, M. R., Morgan, T. K. K. B. 2009. An Indigenous Approach to Engineering Effective Learning Outcomes. In: 20th Annual Conference for the Australasian Association for Engineering Education, 6-9 December, 2009: Engineering the Curriculum.
- Pleasant-Jetté, C. M. and Wiseman, D. 2006. Building a Pathway to the Profession of Engineering for Aboriginal Young People. Canadian Council of Professional Engineers: Ottawa, ON.
(<http://www.engineerscanada.ca/sites/default/files/buildingapathwaytotheprofessionofengineeringforaboriginalyoungpeople.pdf>)
- Shangquan, G. 2000. Economic Globalization: Trends, Risks and Risk Prevention. United Nations: New York, New York.
http://www.un.org/en/development/desa/policy/cdp/cdp_background_papers/bp2000_1.pdf
- Sonnert, G., Fox, M. F., Adkins, K. 2007. Undergraduate Women in Science and Engineering: Effects of Faculty, Fields, and Institutions Over Time. *Social Science Quarterly*. **88**(5): 1333-1356.
- Statistics Canada, 2011. Aboriginal Peoples in Canada: First Nations People, Metis and Inuit, National Household Survey. Ottawa, ON.
- Wagner, W. 2006. The social change model of leadership: A brief overview. *Concepts & Connections*, **15**(1), 9.
- Webley, K. 2012. MOOC Brigade: Will Massive, Open Online Courses Revolutionize Higher Education? Time Magazine. <http://nation.time.com/2012/09/04/mooc-brigade-will-massive-open-online-courses-revolutionize-higher-education/>