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Navigating a Constitutional Moment: Reflections on Implementing Graduate Attributes in Canadian Engineering Education

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This piece is a self-reflexive essay examining our experiences during an important transitional moment, what we will identify as a 'constitutional moment', in engineering education in Canada. We are a collection of scholars who specialize in the study of the interface between technology and the humanities and social sciences (most of us identify as Science and Technology Studies scholars). Housed within the Center for Engineering in Society, itself housed within a faculty of engineering, we find ourselves presented with dual challenges of introducing insights from the critical studies of the relationship between science, technology, and society into the engineering curriculum, while also maintaining legitimacy among the engineering faculty that we find ourselves a part of. This paper is a result of our attempts to understand the challenges in engineering education that are unique to our Canadian context and to systematize our responses to these challenges. The aim of this paper is to share our experiences navigating the relationship between the construction of our center's identity as an Engineering Studies hub and our critical participation in engineering education practice.

Keywords: engineering education; curricular innovation; graduate attributes; scalable scholarship; critical participation; outcomes-based assessment; Canada

Introduction

This piece is a self-reflexive essay examining our experiences during an important transitional moment, what we will identify as a 'constitutional moment', in engineering education in Canada. We are a collection of scholars who specialize in the study of the interface between technology and the humanities and social sciences (most of us identify as Science and Technology Studies scholars). Housed within the Center for Engineering in Society (CES), itself housed within a faculty of engineering, we find ourselves presented with dual challenges of introducing insights from the critical studies of the relationship between science, technology, and society into the engineering curriculum, while also maintaining legitimacy among the engineering faculty that we find ourselves a part of. We are, in essence, engaging in Big STS[1] in which we attempt to scale up our own scholarship to change engineering education and ultimately engineering practice. Unlike Little STS, in which one publishes for an audience typically composed of fellow academics, Big STS requires special attention be paid to pathways of scalability. Here one needs to maintain legitimacy via a careful navigation of varying levels of power, institutions, personal interests, and beliefs. Part of what we want

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[1]For a quick explanation of the distinction between 'Little STS' and 'Big STS', see Downey, "What is Engineering Studies for?" 2009, p. 73.

to share in this piece is our attempt to map the various pathways to scale available to us in our present context.

The piece maps out the idiosyncrasies of engineering education in Canada and our responses to them. Our primary aim in describing our attempts to scale up engineering studies scholarship is to share with other engineering studies scholars our 'notes from the field'. CES is in its nascent stages and so the question of our identity is still very much a live issue. Our university was one of the first in line for accreditation under the Canadian Engineering Accreditation Board's (CEAB) new output-oriented graduate attributes. These unique circumstances have created an opportunity for us to reflexively engage in the production of a tentative engineering studies identity within an engineering faculty that has the potential for real change. We seek to embrace an engineering studies identity that takes engineering practice in Quebec as its unit of study. This identity is shaped by our understanding of the situated agencies that shape the formation of knowledge and techniques in Quebec coupled with the responsibility to scale up this understanding to engineering practice. Unlike some STS scholarship, we do not and cannot pretend to be outside of the agencies that shape engineering culture in Quebec. We are members of the engineering department and are thus ourselves agents in the complex network of engineering practice in Quebec. In this way, we take our own identity formation as an object of study. Our hope is that the stories of our successes and failures in navigating this terrain while forging this type of engineering studies identity will be instructive to other engineering studies scholars.

Background: CES and CEAB graduate attributes

At Concordia, there has long been a tradition of, and administrative incentive for, housing common engineering core courses, such as technical writing, within the faculty of engineering. Rather than contracting English and Math departments to provide instructors to teach sections of the common courses, part-time instructors were hired directly by the engineering faculty to teach sections of these courses. The unique vision of the CES emerged in 2005, when the faculty dean decided to hire tenure-stream faculty with degrees in complementary studies relevant to engineering, including rhetoric, communication, and technology Studies. Subsequent hires in STS and public policy completed the unit. CES was initially configured to centralize those courses common to all engineering disciplines (e.g. math and programing, as well as technical writing and social impact of technology) and was established as a 'service department'. Typically, service fulfill a specific mandate that arises from, and is vital to the evolving vision, objectives, and interests of the engineering faculty. This generally means teaching courses required for undergraduate students in the faculty. This teaching role comes to define the unit in the sense that the departmental identity is expressed by its service to the engineering faculty. Faculty members in the service department are involved in their individual research careers by publishing papers, books, establishing laboratories, and attending conferences, but the collective identity of the department is tied to the topical nature of the courses or certificates it offers.

With the guidance and support of several key champions, the faculty members of CES were given wide latitude to explore and articulate their vision and mission. While CES has no program of its own, its faculty members have co-supervised students in other departments or with the university's independent degree program and supervised post-doctoral students. Furthermore, we are now fully responsible for the required professionalism and responsibility course, all of the required technical writing courses, and the required social impacts course. As CES took on more responsibility, it became more integrated into the engineering faculty and, in our eyes, less of a service department. However, the process is

ongoing and CES members alternately embrace and resist their designation as a 'service unit'. The identification with 'service' is healthy insofar as it encourages members to strive to find ways to improve the practice of their engineer and computer scientist colleagues. Resistance to the service role comes from frustration at the lack of an independent degree program, which constrains research, graduate students, and teaching. These frustrations were identified in a 2008 faculty report and five-year plan for the development of CES; the report noted that the service role would be 'an unnatural existence' for any tenure-stream faculty and that methods and resources had to be found to enable CES to conduct research and work with graduate students.

Another feature of our work within an engineering department is that we run up against attempts to maintain the technical core of engineering. Perhaps predictably, there is a well-respected contingent of very senior faculty members who perceive, or at least rhetorically posit, a dichotomy between technical and soft skills. Soft skills in this dichotomy neither enhance students' ability to put technical knowledge into context nor teach students professionally useful skills, but do threaten to dilute the integrity of technical education. We have found that discussion of the social and ethical attributes is too often only 'window dressing', thinly veiling the entrenched technical and technocratic views of engineering education. For example, our department was unhappy at having to assume responsibility for staffing a half-credit course in sustainability. CES suggested combining it with the half-credit course in ethics taught by CES. This would create a single, full-credit course simplifying staffing and rationalizing curricular content by combining the closely related material of ethics and sustainability. While the department was willing to combine the course, they rejected the idea of giving the course to CES faculty, 'because none of you have the technical knowledge needed'. Not only did this discount the research and academic qualifications of CES faculty, but also defined sustainability as a technical subject. This is an old and ongoing schism within engineering education and the new CEAB graduate attributes are perhaps best seen as the latest discursive rubric under which that contestation is played out.[2]

Efforts are being made by Concordia's engineering faculty (indeed engineering departments across Canada) to comply with new CEAB accreditation requirements. By 2014, all accredited engineering departments in Canada must demonstrate that their graduates possess a series of outcome attributes encompassing technical skills and social awareness. Further, to achieve accreditation from the CEAB, engineering programs must demonstrate that there is a process in place to assess program outcomes and that the results of these assessments are applied to the further development of the program. Most readers are likely familiar with the inclusion of 'non-technical' graduate attributes, such as an 'understanding of the impact of engineering on society' and 'professional and ethical responsibility'.[3] What makes the CEAB attributes interesting is, first, that their implementation creates what we will argue can be understood as a 'constitutional moment' in engineering education in Canada. Second, the CEAB, unlike other accrediting bodies such as Accreditation Board for Engineering and Technology in the USA, is enmeshed in and carries significant authority within a 'closed', regulated professional practice within Canada. CEAB is a constituent of

[2]This is a paraphrasing of Jasanoff's description of the constitutional moment being played out with regard to science governance. Jasanoff, "Constitutional Moments in Governing Science and Technology," 2011.

[3]See Figure 1 for full list of new CEAB graduate attributes. Note the inclusion of an explicit requirement for 'ethics and equity' in attribute 10. In conversation with many US Engineering Studies scholars (e.g. Juan Lucena, a keynote speaker at the 2013 EWB national conference in Calgary) we have found that the inclusion of such language suggests an important difference between the ABET and CEAB graduate attributes.

Engineers Canada, which in addition to controlling accreditation through the CEAB, also controls the obligatory licensure process for all engineers in Canada (through its constituent provincial professional societies).[4] Thus, the new graduate attributes outlined by the CEAB are taken very seriously by engineering departments across Canada. The inclusion of these 'non-technical' graduate attributes and the seriousness with which the new CEAB accreditation requirements are being taken have created a unique opportunity for the members of the CES. At least 9 out of the 12 attributes, shown in Figure 1, involve some role for the social sciences and humanities.

The center has thus been called in from the margins of the prevailing discourses within engineering education and has been asked to help make sense out of these new attributes that have created 'frictions'[5] between the traditional view of engineering education that focuses exclusively on the technical and the very different vision of engineering education that seems to be informing the new CEAB graduate attributes. That there is friction at all, and that these internal tensions are being taken seriously, provides heretofore unavailable ground for us interdisciplinary scholars in CES to stand on. At the same time, other actors push back against the new possibilities. For instance, because the CEAB requirements make it clear that complementary studies must be taught, some faculty members appear to have developed a strategy aimed at tightly restricting the number of CES courses. Nonetheless, we are hopeful and excited about the possibilities available in this constitutional moment.

Constitutional moments and co-production

These frictions create a constitutional moment in which our pathways to scale open up. We borrow the term 'constitutional moment' from Sheila Jasanoff.[6] Constitutional moments are moments in which the basic rules of practice are rewritten, either explicitly or implicitly, thus fundamentally altering longstanding relationships between various actors. They are best seen as opportunities. The new CEAB graduate attributes have provided CES with a codified framework in which it is possible to scale up our STS research into a Big STS attempt to alter engineering education by rewriting of the basic rules of engineering practice. However, constitutional moments are inherently times of uncertainty. In order for real change to be made, the principles enshrined in constitutions need to be genuinely internalized by those the constitution hopes to inform. Thus, we see ourselves in a constitutional moment in which we are presented with an opportunity to make the case for taking graduate attributes such as 'ethics and equity' seriously in the engineering curriculum here at Concordia. As anyone who is familiar with the reception of the ABET 2000 attributes in the USA can attest, the mere presence of such standards and expectations does not guarantee success. However,

[4]Note we say 'all engineers in Canada' not 'all *professional* engineers in Canada'. In Canada, engineering is a tightly closed profession in which both the right to practice and title are regulated. Thus, one can neither call themselves an 'engineer' nor do 'engineering' work without being fully licensed by the relevant provincial professional society (all of which are constituents of *Engineers Canada*).

[5]We use the term friction here in the same way Downey indicated it has been used in engineering science pedagogy to indicate that this tension, internal to prevailing engineering education practice, creates an excellent point of entry for CES. See Downey, "What is Engineering Studies for?" 2009, p. 61.

[6]While she has used the concept throughout her writing, the concept is perhaps most explicitly dealt with in Jasanoff, "Constitutional Moments in Governing Science and Technology," 2011. Jasanoff borrows the term for Bruce Ackerman. Both use the term to discuss democracy. Jasanoff extends the notion to the intersection between democracy and expertise. We use the term here more generally to refer to any attempt to rewrite the basic rules of a practice. Here the CEAB graduate attributes serve as our 'constitution'.

The institution must demonstrate that the graduates of a program possess the attributes under the following headings. The attributes will be interpreted in the context of candidates at the time of graduation. It is recognized that graduates will continue to build on the foundations that their engineering education has provided.
Engineering programs are expected to continually improve. There must be processes in place that demonstrate that program outcomes are being assessed in the context of these attributes, and that the results are applied to the further development of the program.

1. A knowledge base for engineering
Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2. Problem analysis
An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3. Investigation
An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
4. Design
An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.
5. Use of engineering tools
An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6. Individual and team work
An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7. Communication skills
An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8. Professionalism
An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9. Impact of engineering on society and the environment
An ability to analyze social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10. Ethics and equity
An ability to apply professional ethics, accountability, and equity.
11. Economics and project management
An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.
12. Life-long learning
An ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge.

Figure 1. CEAB graduate attributes.
Source: See the website for CEAB "Accreditation Criteria and Procedures". http://www.engineerscanada.ca/sites/default/files/sites/default/files/accreditation_criteria_procedures_2013.pdf.

we feel there are important differences between engineering education in Canada and the USA that make this moment in Canadian engineering importantly different from the US experience with the ABET 2000 attributes.

In order to understand these differences, we employ the concept of 'co-production'[7] in an effort to map out the idiosyncrasies of the Canadian experience with outcome-oriented graduate attributes. We describe various 'measurement loops' in which the tensions between the new visions of engineering education presented in the CEAB graduate attributes run up against entrenched technocratic views of engineering education, in which the non-technical skills of the sort insisted upon by the new CEAB graduate attributes are dismissed as 'soft skills' unnecessary for good engineering. At three different scales we identify a 'measurement loop' in which curricular change and graduate attributes are simultaneously created and measured. Those charged with implementing and defining standards are also in charge of defining metrics of success of implementation, creating a space where knowledge and social order are produced simultaneously. We describe multi-scaled loops through which the graduate attributes make the long journey to actual curricula. We identify problematic moments in which the status quo (the entrenched technocratic view of engineering education) is repackaged and reified in terms of the new CEAB graduate attributes. We similarly identify these moments as potential pathways to critical participation for CES. These moments we identify as contests in which power shifts are possible. The CEAB accreditation process has the potential to give non-technical skills new legitimacy. As a result, CES is going to serve a more central role in decisions about curriculum changes required by the new CEAB graduate attributes. We recognize this role as an opportunity for *critical participation*.[8]

Measurement loops

In this section we map out the topography of the current engineering education terrain in which we find ourselves in an effort to identify the most likely pathways to scalability.[9] We conceptualize this terrain through a multi-dimensional mapping that tries to make sense out of linkages between differently situated actors in the ecosystem of engineering education in Canada. We identify three distinct scales of discourse, practices, and actors surrounding the new CEAB graduate attributes, conceptualizing them in terms of 'loops' created by the mandate for measurement of success of the newly implemented CEAB graduate attributes. In each loop, we identify actors at different levels that are linked in a system of measuring the effects of the new CEAB graduate attributes on engineering education and, ultimately, at the macro-loop, engineering practice. Thus, we, the authors, are not ourselves measuring anything in these loops. Rather, what we identify are loops of measurement; closed feedback mechanisms that, through the very processes of measuring the application of the CEAB graduate attributes, maintain old discourses surrounding many of the non-technical attributes that distinguish the new CEAB graduate attributes from older, more technically oriented accreditation criteria. In a recent article, Erin Cech demonstrates that, despite the many attempts to inject social and political concerns into engineering education, a 'culture of disengagement that defines public welfare concerns as tangential to what it means to practice

[7]See Jasanoff, *States of Knowledge*, 2004.

[8]Downey, "What is Engineering Studies for?" 2009.

[9]Borrowing from Downey's piece once again, we use the term *scalability* in Gramsci's sense to indicate our aim of making our vision of engineering practice a reality. 'Pathways to scale' is here meant to indicate the most appropriate means of scaling up our shared vision of engineering practice.

engineering'[10] persists. We argue that the 'measurement loops' are the mechanisms that reinforce a culture of disengagement in our Canadian context.

Micro-measurement loop

The micro-measurement loop refers to the processes of individual professors (course coordinators) assigned the task of evaluating courses in terms of CEAB graduate attributes. They must define 'indicators' for successful implementation of the attributes, the methods of assessing the indicators (assessment criteria), the rubrics for success, and, finally, the actual content of engineering courses. The micro-loop describes whether and how the outcomes-based assessment affects curriculum change. It is in the micro-loop where the proverbial 'rubber' of the CEAB graduate attributes 'hits the road' (or not). We seek here to map out the processes that individual course instructors go through in applying the new CEAB graduate attributes to the content of their courses and identify problems with those processes that provided us opportunities for critical participation.

We observed that two problems arise in the processes of translation from the CEAB graduate attributes to measurable indicators of student performance. First, how exactly does one measure how well a student has internalized the 'ethics and equity' attribute or the 'lifelong learning' attribute? These are questions that many traditional engineering professors are ill-equipped to answer; yet, the task of translating the attributes into measurable indicators of student performance in a particular course was left to individual instructors. The Undergraduate Studies Committee (USC) charged each instructor with the task of providing four indicators for each graduate attribute that was to be measured in their course. Each indicator then needed to be further deconstructed into two to four assessment criteria, which ultimately determine grade assignments and course success or failure. Finally, a rubric for success or failure was required from each instructor. The only things provided to engineering departments by CEAB are the attribute itself and a general definition of the attribute. The task of further deconstructing what is to be measured in determining successful implementation of an attribute was handed down from the USC to individual professors. An example is given in Table 1 for the attribute, *impact of engineering on society and the environment*, which is defined as 'an ability to analyse social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal and cultural aspects of society'.[11]

A second, but related, problem was that many instructors would use existing course syllabi as sources of definitions of indicators, assessment criteria, and rubrics for success for the new CEAB graduate attributes and professors believed that their courses were already meeting the outcomes criteria. Thus, existing pedagogy was repackaged and presented as a way of assessing new graduate attributes and we observed at USC meetings that such repackaging was not experienced as problematic among most faculty members. For example, professors from material sciences were happy to report that they already were discussing various differences between insulation materials which could easily appear to have an effect on students' understanding of social and sustainability issues. As another example, during the USC meetings we were presented data on how well the attributes were being delivered based off of these existing syllabi and student grades. Yet, as evidence of this, they offered, for instance, an existing assignment on factors that affect fatigue life to

[10] Cech, "Culture of Disengagement in Engineering Education?" 2014, p. 45.

[11] Written and approved by the USC at Concordia University in preparation for CEAB accreditation in 2011.

Table 1. An example of attribute indicators and assessment criteria.

Indicators	Assessment criteria
1. Knowledge base	• Recognize relevance of societal impact of engineering to improving innovation • Categorize the breadth of engineering and society relations including economic, social, health, safety, legal, and cultural aspects • Demonstrate familiarity with evolution of technologies
2. Social and environmental analysis	• Analyze impact of engineering on society and environment • Diagnose complex social and environmental issues • Frame arguments and communicate analysis (related to the communication skills attribute)
3. Sustainability in design	• Identify social and environmental protection issues • Frame research questions • Locate challenges to sustainability from technological design
4. Technology and society models	• Gather and present information • Design a strategy for incorporating social sustainability • Assemble a technology model that preserves social sustainability

indicate how well students understood the impact of technology on society. As one senior administrator summarized the situation:

> Several times when we discuss about particularly the design issues with different groups of colleagues, I feel that they are in a little bit of denial, or they really thought that in our traditional way of giving the education, we are actually covering these kinds of subjects [impact of technology on society, ethics] in our basic training process… But we are really not. Our education is not putting the students in a mindset that they will always think about those kind of at least six, seven different attributes into their design in every step. They don't do this thing. That is not natural. That is not our culture. That is not part of our faculty's culture either.[12]

Short of a more thorough definition provided by CEAB, one can see why many professors, unaccustomed to thinking about things such as ethics and equity or social impacts of technology on society, chose this path. This process, however, creates a clear, closed loop into which no real change can enter. As members of the USC, we recognized these interrelated problems as an opportunity to critically participate in the micro-loop. Our main pathway to scale in the micro-loop was to put together presentations on how, informed by our STS training and research in engineering studies, each of the graduate attributes ought to be broken down into constituent indicators, assessment criteria, and rubrics for success. We presented these to department councils composed of course coordinators, department heads, and general faculty. In these presentations, we tried to convey three major points. First, we wanted to draw the attention of faculty members to the four graduate attributes (attributes 7–10 in Figure 1), that given our disciplinary backgrounds, CES helps address. Second, we presented CES as a learning resource located in the faculty that could help faculty members measure attributes. Third, we suggested specific pathways through which we could help individuals assess attributes such as impact of engineering on society and communication skills. After the presentation, we circulated a resource handout for faculty members who would like to rely on CES expertise.

[12]Personal communication with senior administrator provided on condition of anonymity, 22 January 2014.

The presentations were received well, suggesting that the micro-loop was not only the result of faculty resistance to curriculum change, but also a genuine need to be pointed in the right direction. Future meetings of the USC revealed that this particular intervention (defining the attributes and how they were assessed) was a successful one. CES has now helped several departments write up their assessment criteria for the graduate attributes. A great example of this was with attribute 7: communication skills. Both the mechanical and electrical engineering departments were asked to assess the communication skills of their students across a number of technical courses offered by these departments. CES was able to work with these departments to write the indicators to be assessed for this attribute. We were able to successfully lobby for the inclusion of the notion of 'engineering in context' in how the indicators for the attribute were measured. This included language such as 'Students can adapt presentation to heterogeneous audiences', 'Students can identify audience needs, interests, and level of knowledge', and 'Students can respond to critical feedback'. This language shifts focus from how the engineer understands and talks about her work onto the audience and the context in which the engineer is practicing. It emphasizes a bilateral understanding of communication as dialogue. In this way, we hope to have injected a measure of reflexivity about the engineers' roles in society into how 'communication' is thought about and taught about in technical courses. While there are many other attributes that continue to suffer from the closed loop problem identified here, we have, for now, found a small place where we hope a big difference can result.

Meso-measurement loop

The meso-measurement loop refers to the relationships among actors within the university engineering faculty: the dean (administrative head), associate dean (AD), course coordinators, and professors/instructors. The dean is ultimately in charge of implementing the attributes. The managerial responsibilities are delegated to an AD. The AD works with course coordinators in the engineering department, who in turn work with individual professors. The individual professors, however, are mired in the above-described micro-loop dilemma. The results of how the nominally reformed course material is being measured by individual professors are then fed back to the dean and understood to be a gage of how well the new attributes are being implemented. The frictions experienced in this loop relate to working with administrators who support change and faculty who believe it is unneeded.

Our pathways to scale in this loop have thus involved activities, supported by our dean, that facilitate modest cultural shifts within the faculty as a whole. Our interventions have mainly come in the form of faculty-wide events such as colloquia, panel discussions, and more informal *cinq à sept*[13] receptions. These events are advertised to all of the engineering departments and often involve speakers from multiple departments. In order to infuse the events with the type of social and humanistic values that are represented in many of the CEAB attributes, we also often invite members from other faculties beyond engineering, such as Business, Fine Arts, and Arts and Sciences, who speak on panels alongside engineering faculty. Attitudinal and cultural shifts can occur when faculty members see that the social and ethical implications of engineering (i.e. what is being mandated by the CEAB attributes) are not only non-threatening, they can also be interesting and enrich technical instruction. To the extent that we are able to help bring about these shifts, we feel our

[13]Literally translated 'five to seven', the *cinq à sept* is a staple of French–Canadian culture and allows an opportunity for guests to informally mingle over drinks after short formal remarks.

interventions can disrupt the typical window dressing operation of the meso-measurement loop and present a potential pathway to scale at this level.

One particular event shows the type of modest cultural shifts that our interventions can have at this scale. For the last two years, CES has worked with students from the Concordia University chapter of Engineers Without Borders (EWB) Canada to co-organize a Global Engineering week. The week is filled with events that highlight the role of engineering in the world and the social and cultural dimensions of engineering practice, particularly practice in developing countries. Members of the CES faculty took part in week-long events, such as daily 'Lunch and Learns' with titles including: 'Innovative Solutions to Global Engineering', 'Multi-stakeholder Engagement and Intercultural Competence: Working Effectively Across Cultures in Global Engineering and Society', 'Design Thinking in the Era of Sustainability: Beyond Eco-efficiency Strategies', 'Why You Are Not Ready to be an Engineer and What is in Your Power to Change', and 'Design, Innovation, and Engineering', among others[14]. These events were facilitated by (and more often lead by) CES faculty members. In addition, CES faculty members helped organize speakers from across North America to help lead these events (more on this below).

At last year's Global Engineering week, EWB announced a new EWB Global Engineering Teaching Award. CES served as consultants on how to frame criteria for the selection of a winner. The students were then asked to vote for the professor that they felt introduced Global Engineering into the classroom most engagingly. Ultimately, the criteria for nominations reflected the social and ethical dimensions of the new CEAB attributes. This was in hopes that the award would serve to first bring attention to the new CEAB attributes and second to motivate *and incentivize* professors to incorporate these attributes into their curriculum in *new* ways. As we saw in the micro-loop, many professors operate under the assumption that either the current curriculum already deals with the social and ethical implications in an appropriate way or that they simply do not need to focus on the 'softer' skills outlined in the new CEAB graduate attributes. Here, we attempted to perform our Engineering Studies identity by helping to draft the specific requirements that professors would need to meet to be eligible for the award. These included genuine engagement in *new* and *innovative* ways with the social and ethical implications of the technical content of their course.

Members of the CES faculty were not qualified to be nominated so as to limit the pool of nominees to only those professors who teach technical courses. Last year Professor Christopher Willis was given the award for his inclusion of the non-technical attributes (especially attributes 7–10 in Figure 1) in courses, such as Engineering Management Principles and Economics, Construction Engineering, Project Cost Estimating, and Construction Processes. It is the hope of CES and EWB Concordia that this award will further motivate and incentivize other professors to be creative in engaging students with the non-technical CEAB graduate attributes. (Figure 2)[15]

Another simple, yet effective strategy implemented during these Global Engineering weeks has been to invite people who have had some success in incorporating Global Engineering into existing curricula at other universities. Last year we invited Dr Domenico Grasso to give a keynote on 'Holistic Engineering'[16] and talk about his success at the University of Vermont. After the keynote, the culminating event of the week was a *cinq à sept* reception. The event was held in the faculty lounge and was widely attended by faculty

[14]More detailed information about coming events and past events can be found at: http://concordia.ewb.ca

[15]Global Engineering Award Criteria, http://concordia.ewb.ca/ (accessed March 14, 2014).

[16]See Grasso and Burkins, *Holistic Engineering Education*, 2010.

The Global Engineering Award (GE Award) is intended to recognize the contribution of a professor in the Faculty of Engineering and Computer Science for their contribution to Global Engineering practice.

To be nominated for the award, the ENCS professor should demonstrate excellence in one of the following GE areas through their teaching:

Problem analysis:
Highlights the complexity of the subject by going beyond equations and guidelines

Design:
Mentions innovative and creative design possibilities.
Mentions design possibilities from around the world, both in developed and developing countries.
Offer design opportunities for students on open-ended or complex issues.

Use of engineering tools:
Include tools, techniques and theories from social sciences to complement the engineer's mathematical toolbox.

Individual and team work:
Make students work on team projects, either during class time or as an assignment.

Communication skills:
Offer students opportunities to practice their communication skills
Favor the active participation and contribution of the students
Include formal and informal oral presentations

Impact of engineering on society and the environment:
Include topics of sustainability and mention green options
Mention the impact of the subject on society, both at the local and global level and mention fair options.
Include a research paper where the students explore the impact on society and the environment of a topic related to the course.

Ethics and equity:
Link the subject to present or past ethical debates

Award criteria
The nominated professor must:
-be a member of the ENCS faculty at Concordia (either full-time or part-time). Professors housed in the Center for Engineering in Society are excluded.
-demonstrate one or more of the global engineering teaching aspects outlined above, preferably in all of their classes

How to nominate a professor:
Email a paragraph describing why the professor should get the GE award to ewb@ecaconcordia.ca. Paragraphs should be approximately 150 words. Please include your name and area of study.

Selection Criteria:
The winner will be selected based on the quality of the nomination. Multiple nominations by different parties is viewed favourably by the award committee.

If a suitable candidate is not nominated by the ENCS student body, the EWB GE Award committee reserves the right to choose an awardee themselves.

Deadline: Friday, March 7th, 2014

Figure 2. Award criteria.

members from many of the engineering departments. The dean of the faculty had been involved in the planning for Global Engineering week from the inception stages. At the event, the dean stood up to make a small speech about Global Engineering. During his speech, he discussed the role of CES in the engineering faculty. In doing so, he was about to use the term 'soft skills' to describe what CES does, but he suddenly caught himself and used another term 'engineering skills'. This shows how the dean's attitude has shifted from the more traditional hard vs. soft skills viewpoint (discussed above) toward an appreciation of the importance of broad integration of social values into engineering education.

Macro-measurement loop

The macro-measurement loop is organized at the level of the Canadian nation-state. The key actors in this loop are the CEAB that monitors and accredits individual degree-granting educational institutions; Canadian universities that produce qualified engineers; and professional societies that supervise and regulate the profession in Canada. The logic of the macro-loop suggests that in response to the changing needs of industrial engineering practice, CEAB alters the skills and competencies needed by engineering graduates. In response to accreditation pressures, universities shift the skill base their graduates possess and this accordingly is reflected in the changing membership of professional societies, which will eventually influence the practice of engineering.

Another actor in this loop is the Engineering Graduate Attribute Development (EGAD) project. For individual universities and senior administrators, the challenge of transforming their curriculum in order to implement graduate attributes can be a daunting task. EGAD is an inter-university collaborative endeavor between the National Council of Deans of Engineering and Applied Sciences and CEAB designed to help implement graduate attributes in the curriculum. The annual conference of the Canadian Engineering Education Association (CEEA) is an important venue where educators encounter the EGAD project. Through papers presented at the conference and sponsored workshops, EGAD has emerged as a vital resource for accreditation. Concordia University is one of the 10 Canadian universities that collaborated to found the EGAD project.

An AD at Concordia University works closely with other universities collaborating in the EGAD project to coordinate attribute assessment. We at CES have had the opportunity to work closely with the AD and have utilized this opportunity to engage more closely with the AD on the topic of attribute-based assessment. One means that we have adopted has been to co-author papers for the CEEA conference with the AD. These papers have provided an opportunity for CES and the AD to closely discuss not only the implications of accreditation at Concordia, but also the attributes assessment process and shifts in Canadian engineering education more generally. Engineering education around the world has sought to respond to the challenges posed by the internationalization of engineering work and the transnational mobilities of engineers.[17] The changes in the accreditation process in Canada, we point out, parallel efforts undertaken by other regions as they 'rethink the competencies of engineers and the contents of engineering education'.[18]

For example, in a recent paper titled 'Creating Faculty-Buy-in'[19] we investigate some of the challenges, especially those of leadership, in implementing new accreditation criteria.

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[17] Downey and Lucena, "National Identities in Multinational Worlds," 2005.
[18] Lucena et al., "Competencies Beyond Countries," 2008, p. 433.
[19] Gopakumar et al., "Creating Faculty Buy-in," 2013.

Specifically, we sought to draw attention away from the pervasive definitional and information management (bean-counting) challenges associated with the accreditation process and focus instead on the leadership challenges that have roots in entrenched factors associated with the sociocultural aspects of university education. A key recommendation we made in the paper was that understanding faculty culture through an appraisal and evaluation exercise (that we at CES could accomplish given our ability to study complex socio-technical contexts) would allow leaders of the attribute assessment exercise to understand sources and stimuli for resistance in engineering faculties. We suggest that the culture of resistance to the attribute-oriented accreditation process has parallels with a prevalent culture of disengagement in engineering education with regard to wider social and ethical issues.

As a senior administrator in the faculty mentioned earlier noted,

> Our education is not putting the students in a mindset that they [faculty] will always think about those kind of at least six, seven different attributes into their design in every step… That is not part of our faculty's culture either.[20]

The culture of the faculty referred to produces not only the culture of resistance to the accreditation process, but also the culture of disengagement from the social context of engineering. This is especially true because accreditation and its incorporation of non-technical attributes appear to many faculty members as a process that is threatening to established faculty culture. An assessment exercise that therefore understands the culture of a faculty makes visible not only the culture of resistance to accreditation, but also becomes an opportunity to make visible the sibling culture of disengagement from society. Assessing cultural sources of resistance to accreditation also assesses cultural sources of disengagement. Doing so creates the context for a faculty conversation regarding how accreditation is the seed for a sustained cultural transformation in engineering education. At the macro-level, our motivation has been to utilize the working relationship between CES and the AD to convey our perspectives through our paper to the national EGAD project. We see this as a pathway for CES to intervene in the process of articulating new cultural shifts in Canadian engineering education. The paper and its recommendation for an exercise in cultural assessment thus become an opportunity to influence the development of a critical Engineering Studies identity at the macro-level.

Another way that CES has intervened in the macro-loop is through a partnership with the national chapter of EWB Canada. The objective here is to work in partnership with EWB Canada to articulate a critical vision of sustained social engagement with key non-academic macro-level actors: industry and engineering professional societies. For CES, Global Engineering is the pathway to scale this vision of critical participation. At the 2012 national conference, the authors were invited to join senior professors and administrators from engineering schools across Canada in a Global Engineering Symposium that discussed the new CEAB graduate attributes in terms of EWB's goals. At this meeting, the seriousness of reform efforts in engineering education spawned by the non-technical skills included in the new CEAB graduate attributes was evident. Following that meeting, CES established a collaborative relationship with the Global Engineering Team Lead for EWB Canada. The initial meeting at the national conference convinced CES that Global Engineering was a vital platform for collaboration and more importantly an avenue for critically engaging industry and engineering professions at the macro level.

[20]Personal communication with senior administrator provided on condition of anonymity. 22 January 2014.

A key first step was the partnership that one of the authors and EWB entered into to develop a Global Engineering course. The details of the partnership with EWB Canada and the process of course development are described in more detail elsewhere.[21] For our purposes here, it is important to note that the course had two key 'knowledge thrusts': complexity of development processes and informality in decision-making and information flow in societies of the global south. The development of this course employed a consultative methodology that incorporated opinions of students, EWB staff, and professionals working in the local area. The consultative methodology entailed brainstorming with EWB-Concordia members; employing a questionnaire and interviews to determine what students needed from the course; and consultation on disseminating the findings and publicizing the course. The appendix presents the syllabus of the Development and Global Engineering course.

This partnership was instrumental in the author being invited by EWB Canada to speak to industry representatives and EWB professionals at the Global Engineering Symposium. Here the author had the opportunity to present his vision of Global Engineering (based on the two key knowledge thrusts of his course) that calls for the engineering industry engaging more closely with complexity and informality in the globalizing world. Borne out of this vision of Global Engineering is the suggestion that the engineering industry and practice should engage with society on society's terms rather than the other way around. In other words, taking social engagement seriously requires making social and political values underlying technological choices explicit. While some of his ideas of avoiding technological lock-in were better received, there was less enthusiasm for social and political alliance-building that would have to accompany any move to take society seriously. In general, the author's ideas had far less impact than that of a proposal for an engineer-entrepreneur. A key lesson was that a critical vision of Global Engineering that takes society and its messiness seriously is troubling for established actors. More palatable is the ability of entrepreneurship to solve global problems. Global Engineering, we learned, offers a pathway to participate and present our critical vision of Engineering Studies. However, the challenges we face bring to the forefront the tentative nature of interventions proposed here.

Conclusion

CES is uniquely positioned in several ways and we have recently reached the consensus that we will best promote socially responsible engineering practice by embracing an Engineering Studies identity. This identity is characterized by our commitment to provide engineering students in Quebec with the knowledge and skills to reflexively engage with the larger context in which they will practice engineering. Indeed, this paper is both product and emissary of the process of articulating that identity and its associated pedagogical agenda. This process provides us with a rare opportunity to reflexively engage in the work of forming an Engineering Studies hub with clear goals and interventions in mind. CES is recognized as part of the engineering faculty, in distinction to other models where engineering students go outside the school of engineering to take complementary courses in other faculties (e.g. English, STS, Ethics, etc.) Positionality matters a great deal to our narrative. It is rare, in that we are not coming in from outside the engineering faculty. We are a center within the school of engineering and are recognized as an important part of CEAB compliance efforts. We seek here to make sense out of how to best construct a critical Engineering Studies identity informed by our STS backgrounds, while also making sure we do not position ourselves as 'other' from the rest of the engineering department we find ourselves a welcomed part of.

[21] Gopakumar, "Teaching Global Engineering in Canada," 2013.

Critical participation requires participation, which involves politically sensitive attempts at scaling up a critical approach to Engineering Studies from within an engineering department. On a local level we are faced with the challenge of how to best forge an Engineering Studies identity (in terms that can be seen as legitimate by the rest of the engineering faculty while retaining the critical edge inherent in our STS training). On a global level we are simultaneously faced with the challenge of harnessing the potentially constitutional moment that the new CEAB graduate attributes have constructed. Thus, CES is in unique position. We are a center that is both nominally a part of the engineering faculty and, crucially, recognized as a necessary participant in Concordia's plan for compliance with the new CEAB graduate attributes. While, because of our positionality, we are, perhaps, in more danger of co-optation than most Engineering Studies hubs,[22] we have an opportunity to take advantage of our close proximity to the center of prevailing engineering education practices and discourses than is typically enjoyed by Engineering Studies hubs. Our challenge is to craft an Engineering Studies identity that is sensitive to the potentially increased danger of co-optation while also crafting an identity that does not alienate us from those in the mainstream of the prevailing engineering education discourse who, for now, recognize us as important and necessary voices in reshaping the engineering curriculum. Yet, the image of a service department remains a key constraint. CES' efforts at participation (critical or otherwise) remain hamstrung by its institutional location. Our desire to reconcile the twin pulls of forming a critical Engineering Studies identity with our location in a traditional engineering faculty has generated a great deal of reflection on the particular departmental model CES ought to embrace.

Despite such challenges, however, CES also enjoys certain advantages. While CES members may appear to be in some sense marginalized due to the courses they teach and the non-technical research agendas, they actually enjoy some unexpected advantages. Despite being a small department without an independent program, CES is a full participant in the engineering faculty's administrative structure. It has a chair with the same rights and responsibilities as other engineering departments, participating in executive committee discussions, industrial advisory board meetings, and other administrative events at the faculty and university levels. Another advantage is that the center's existence at the interface between engineering and other disciplines allows members the opportunity to assume administrative roles normally reserved for senior faculty members at the faculty and university levels. CES members have the advantage of their humanities and social science backgrounds when interacting with colleagues from across the university and frequently provide an 'easy entry point' into engineering faculty for colleagues from other departments. This has enabled CES faculty members to enjoy relatively rapid ascent up the career ladder. A third advantage is that CES occupies a neutral territory within the engineering faculty and is an accessible site for interdisciplinary discussion of social issues related to technology. As a result, CES has been able to host a number of high-profile panels, speakers, and events that resonate university wide.

We hope that our experiences in the three measurement loops can prove useful to those who find themselves in similar situations now or in the future. We also hope that this paper serves as a meta-analysis of our experience with Engineering Studies as an identity, as well as a practice in Engineering Studies (i.e. mapping out actors, identifying frictions, and implementing a strategy for scaling up our research). We recommend that anyone involved with the social and political training of engineers engage in a similar process. The writing

[22]Downey focuses on the tension between scalability and co-optation: See Downey, "What is Engineering Studies for?" 2009.

of this article provided the members of CES with an opportunity to collectively reflect on what we do, how we do it, and why we do it; that is, to reflect on who we are and who we want to become.

We aspire to grow beyond our service mission by offering programs that enrich the educational experience. As an asset to the college of engineering, we would like to begin offering dual degree programs or collaborative efforts with other engineering departments at both the undergraduate and graduate levels. We are already well into the process of establishing graduate certificates in Global Engineering and Social Entrepreneurship. In addition, we have served on several PhD committees within the engineering department. The Design, Innovation and Society program administered by the Science and Technology Studies program at Rensselaer Polytechnic Institute provides one model we would like to follow. The department offers a unique interdisciplinary design training experience for undergraduate mechanical engineering and computer science students. This program offers a series of design studios that are co-taught by faculty members in mechanical engineering/computer science and the STS department.

Given growing public concern about such issues as the impact of technology on society and the telos of unrestrained technological development, the 'moment' for a more reflexive engineering practice is at hand. CES is being called in from the margins and has seized an opportunity for 'entry' into the heart of the prevailing engineering education discourse at Concordia University at a time when CES is attempting to shape itself into an STS-informed Engineering Studies hub. We are excited about the opportunity to reflectively engage in shaping a more mature identity for CES and the unique opportunity that this 'moment' in Canadian engineering education history offers. We take seriously the challenge presented in Downey's piece 'What is Engineering Studies for? Dominant Practices and Scalable Scholarship' to scale up our STS scholarship.[23] This constitutional moment comes at a time when CES is primed to create interventions into the core of the engineering faculty. If CES is a viable model for creating such reflective engineering practitioners, this moment could prove to be constitutional for us as a center, as well as for engineering education in Canada. Only time will tell. Such is the nature of constitutional moments.

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[23] Downey, "What is Engineering Studies for?" 2009.

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Appendix. Course Outline, Fall 2012

ENCS 498B EE/2: DEVELOPMENT AND GLOBAL ENGINEERING
Thursday 1745-2015
Instructor: Govind Gopakumar, (govind.gopakumar@concordia.ca)
Office hours: MONDAYS & WEDNESDAYS, 3-4PM or by appointment.

COURSE DESCRIPTION: What is development? Why are some countries more developed than others? What role can engineers play in international development? What are some analytical skills, planning and strategic tools that will allow engineers to manage development projects? The course is designed to address two broad dimensions in international development. The first half of the semester will provide a macro-level understanding of development and developing societies – their history from colonial times; the tensions, politics and challenges associated with the process of change. The focus in this part of the class will be on the complexity and informality of developing societies. In the second half of the course we understand development at the micro-level as practices and projects. We will dedicate this half of the semester to engaging closely with the complexity of working and doing development at the community level. We do this by focusing on two aspects – first, strategies of facilitation to work with people, and second, a range of tools and skills needed for data gathering, strategic planning, gender analysis etc. Throughout the course we will utilize classroom discussions, case studies and project planning exercises to stimulate interactive learning for the students and the instructor.

REQUIRED TEXT: There are two required texts for this course.

(1) *Geographies of Developing Areas – Global South in a Changing World* by Glyn Williams, Paula Meth and Katie Willis, 2009, Routledge: New York, NY.
(2) VeneKlasen, L and V. Miller. 2007. A New Weave of Power, People and Politics. Practical Action Publ.: Rugby, UK,

SUPPLEMENTAL READINGS: In addition to the textbook I will prescribe some readings that will be available online on the Moodle website for this course.

COURSE SCHEDULE

Week 1: The Developing South & Development
September 6 – Readings: Williams Chapter 1

Week 2: Society, Polity, and Economy of Developing Regions
September 13 – Readings: Williams Chapters 3, 4, & 5

Week 3: Politics, Economics and Cultures of Living in the South
September 20 – Readings: Williams Chapters 6, 7, & 8

Week 4: Making Change – Governments, Markets and Civil Society
September 27 – Readings: Williams Chapters 9, 10, & 11

Week 5: Current directions in development
October 4

Readings: Zafarullah, H and A Shafiqul Haque. 2012. Managing Development in a Globalized World – Concepts, Processes and Institutions. CRC Press: Boca Raton, FL, Chapter 4.

Week 6: Politics of Doing Development – For Whom? And How?
October 11 – Readings: VeneKlasen Chapter 1 & 3.

Week 7: Development as Planning
October 18 – In-class Quiz
Readings: Wates, Nick. 2006. *The Community Planning Handbook*. Earthscan: London, p.2-21.

Week 8: Planning Exercise 1 - Context Mapping
October 25 – Readings: VeneKlasen Chapter 7.

Week 9: Development through Facilitation 1
November 1
Readings: Dodge, Cole P and G Bennett. 2011. *Changing Minds – A Guide to Facilitated Participatory Planning*. IDRC: Ottawa, Canada, Section C.
(Free to download:
http://www.idrc.ca/EN/Resources/Publications/Pages/IDRCBookDetails.aspx?PublicationID=865)

Week 10: Planning Exercise 2 – Identifying and Prioritizing Problems
November 8 – Readings: VeneKlasen Chapter 8 & 9.

Week 11: Development through Facilitation 2
November 15
Readings: Dodge, Cole P and G Bennett. 2011.
Changing Minds – A Guide to Facilitated Participatory Planning. IDRC: Ottawa, Canada, Section D

Week 12: Planning Exercise 3 - Forcefield & SWOT Analysis
November 22 – Readings: VeneKlasen Chapter 12.

Week 13: Project Presentations
November 29 – Presentation of development plans; submit essay and final project reports