LEVERAGING NETWORKS: ONLINE NETWORK BASED LEARNING FOR 21ST CENTURY ENGINEERING EDUCATION AND PRACTICE

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Abstract: How can engineering students be prepared for their career in the 21st century? For over 10 years, Engineers Without Borders Canada (EWB) has advanced the concept of the ‘global engineer’ as one approach to this challenge. The global engineer is a technically competent engineer with excellent communication and leadership skills, as well as a developed awareness of globalization and sustainability. The current engineering curriculum offers many tools and resources to prepare students for the unique challenges and opportunities that the 21st century will present. However, there is a great opportunity to leverage recent advances in online learning and network/community based learning to enable students to further connect to these 21st century concepts. This paper outlines the architecture of an online platform as well as its approach to pedagogy and developing a Canadian learning network for global engineering.

1 GLOBAL ENGINEERING: LESSONS FROM THE CLASSROOM

1.1 Background
This paper outlines fundamental values of a global engineering pedagogy, and uses them to inform an architecture for an online platform for developing a Canadian learning network for global engineering. Our hope is that this platform, the Global Engineering Initiative, will serve as a virtual and global home and clearinghouse for an ever-growing community of ethical and informed practitioners of global engineering. For some, preparation for global practice may simply mean the ability to schedule team meetings over several time zones, say a few words in a local language, and comply with a variety of seemingly incommensurable labour regulations. However, for others, global engineering means the responsibility to practice in a way that improves not just local lives, but skilfully addresses the complexities of an interdependent world (Lucena et al., 2006). For over 10 years, Engineers Without Borders Canada (EWB) has advanced the holistic concept of the ‘global engineer’: a technically competent engineer with excellent cross-cultural communication and leadership skills, a sophisticated understanding of the processes of globalization, as well as a developed awareness of social and environmental sustainability. This vision of the global engineer is time-consuming and expensive to implement. We argue that recent advances in online learning and network/community based learning can be leveraged to enable students to further connect to these 21st century concepts (Bourelle, 2014; Bowen, 2013).

1.2 Fundamental Values for Global Engineering Instruction
Our work with global engineering began with a classroom course, developed by one of the authors (Govind Gopakumar) in 2011. The course itself was possible as a result of the pioneering Centre for Engineering in Society (CES), an interdisciplinary academic unit housed within the Faculty of Engineering and Computer Science at Concordia University (Gopakumar et al 2012). CES encourages the study of technology/engineering practice and research. The curriculum for the global engineering course was based on extensive interviews with practicing global engineers and students returning from EWB’s Junior Fellows placements (Gopakumar 2014). While the course has been successfully offered several times to
classes of up to 50 students, we saw the potential to progressively develop the curricular scope of global engineering education. We conceived the idea of a virtual global engineering clearinghouse, and realized that this was not an isolated idea; the national headquarters of the EWB Canada was imagining a global engineering learning platform with international reach. Three main pedagogical aims informed the course in global engineering, and would serve as the guiding principles of the online platform development. These aims were:

1. **An appreciation for the context of engineering practice**;
2. **An understanding of methods for intervening within a social context**;
3. **The development of an ethics of progressive change**.

1.2.1 An appreciation for the context of engineering practice

An appreciation for the context of engineering practices is a vital element of a course on global engineering. This requires students to become aware of the social, cultural, economic and political contexts that surround any engineering intervention. Such contextualized thinking is particularly relevant for interventions located within developing communities (Lefevre et al., 2000; Dodge & Bennett, 2011). This is so because these locations often possess ways of interacting or making a living that appear quite different from contexts that demonstrate an ‘industrial modernity.’ A global engineering course could achieve this objective through a substantial instructional component that focuses on the processes of change in the social, cultural, economic, and political life of individuals in developing contexts. Such an instruction should deliver in the minimum a broad brush understanding of how these contexts are changing as a result of globalization.

1.2.2 Interventions that fit social contexts

A second pedagogical aim of a global engineering course is to instruct students on a range of methods that promote interventions mindful of social contexts. Engineering has for long been characterized by scientific interventions that can be dropped into place without paying attention to contextual aspects. Global engineering attempts to break free from this legacy by inculcating practices that account for context. Thus interactive, collaborative and consultative methodologies that embody the spirit of participation are particularly appropriate for global engineering. This aim can be achieved through the use of multiple case studies of successful interventions that describe the process followed by engineers to accomplish their aims. Such a case study approach is particularly useful for understanding how to intervene (Scherer et al., 2011).

1.2.3 An ethics of progressive change within engineers

An ethics of progressive change seeks to develop an attitude or mindset amongst student engineers whereby they are inclined to foster, through their interventions, societal changes that favour values of social justice, equality, and environmental sustainability. This aim can be achieved by directing students into collaborative engagements with progressive grassroots groups around the world. It has been widely accepted that working with such groups allows students to acquire an ethical orientation for progressive change (Lefevre et al., 2000; Lucena et al., 2006).

2 THE ARCHITECTURE OF NETWORKED LEARNING

We have hypothesized that there is an opportunity to transfer parts of the above outlined global engineering pedagogy to an online space. The rise and widespread popularity of Massive Open Online Courses (MOOCs) has supported this hypothesis, however exactly how effective online learning tools are inherently is an ongoing debate (Garrison & Cleveland-Innes, 2005). It has, however, been demonstrated that online tools can be effective in supplementing overall learning outcomes, particularly when a student centred design process is followed (Knowlton, 2002; Bowen, 2013).
The planning process began by asking relevant questions to clarify the pedagogical aims. How to achieve these outcomes in the ambiguous and uncharted territory of online learning has been the greatest challenge. The guiding questions that we ask in a global engineering context were used to develop the vision for the site:

- What is the context where we want to intervene?
- What are some historical factors that will influence an intervention in this context?
- How can we better understand the needs and wants of the stakeholders?
- Who are progressive actors involved in making changes in this context?
- How can we work in collaboration with progressive actors?

2.1 Establishing demand

The first major question we sought to answer was to establish whether a demand existed for such an online hub. Although we felt it would be a worthwhile investment, we wanted to survey the community to better understand whether there was a widespread need for such a tool. We also hoped to better understand whether an effective one already existed that we might not have been aware of. We asked: what do students, professors and professionals across Canada currently use to meet their content, community and learning needs for global engineering education? It became clear after the first four months of progressive engagement that there was widespread demand for such a website, but none currently existed that would sufficiently fill the gap. The project was validated by over thirty interviews with major players in the global engineering realm. But to ask these players to articulate what such a platform would look like was a daunting task.

At the beginning of the project a review of sites offering global engineering type pedagogy was completed. Each site was analyzed based on three criteria:

- Content delivery mechanisms
- Opportunities for social network integration into education
- Content’s ability to convey engineering and leadership skills that enable engineering students to practice engineering in a globalized world

This review was conducted by multiple stakeholders, including professors, industry, nonprofit leaders, and students to determine whether the sites met the needs of what the initiative was trying to accomplish.

Two major sites were identified as providing online learning approaches to global engineering content: Global Dimension in Engineering Education (http://gdee.eu/) and Engineering for Change (https://www.engineeringforchange.org/). Global Dimension in Engineering Education provides open PDFs that users may download for free. These can be followed as chapters that the user can pursue at their own pace. Although the content is substantial, there is no major emphasis placed on networking between users on the site. As this was identified as a major target area for the GEI platform, it was determined the full build out of the platform would be a novel contribution to the engineering education space by allowing users to co-create and curate learning opportunities using social networking functionality.

The Engineering for Change platform offers a similar theme to the GEI platform, however the functionality of the platform differs. The GEI platform is targeted specifically for undergraduate and graduate students who seek to access resources and learning support in developing their engineering, leadership, and global competencies. The learning environment developed by the GEI platform is integrated with a certificate program which has been piloted at the Memorial University of Newfoundland and will be
implemented at additional partner schools in 2015. This direct tie in provides a unique educational experience that strongly aligns online global engineering content with a student’s university experience. Additionally, the plan for the GEI is to curate the online hub with a distinct set of learning outcomes that are currently in development with industry and academic partners. The structure will focus on core content developed by major institutions, such as universities, which is peer reviewed, yet an additional novel contribution we see the GEI making. Additionally, the GEI platform is scoped to allow for user generated content that is moderated and sorted by the GEI team. Although users may complete tasks on Engineering for Change, the experience is less structured and does not require that users follow a pre-designed path, nor is the education directly integrated with a certification process or on-campus learning.

![Figure 1: Outline of the GEI architecture](image)

Figure 1 outlines the overall site architecture and how the pedagogy criteria of the GEI are linked through site architecture.

### 2.2 Strategy

It was decided that the most practical and effective approach to designing and building the site would be to launch and test in several iterations over a timeline of at least two years. By establishing a significantly long timeline, we hoped to involve a maximum number of stakeholders, while increasing feedback at each of the beta stages. At four months the first beta was launched consisting of a combination of publications, video lectures, presentations and case studies. A collaborative approach was used to develop the initial site structure as well as curate the content. From a design perspective, the platform is now able to host material in a robust and scalable way, and has sought to keep the user interface relevant by engaging end users throughout the entire development process (see Figure 2).

![Figure 2: Evolution of the library over 8 month time period](image)
Additionally, the library is now able to supplement the human-readable resource library (the website) with a machine-readable web service. The current site classifies content according to five different taxonomies but several other possibilities have been identified in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1: Library Taxonomies and Data Queries</th>
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<tbody>
<tr>
<td>Current taxonomies</td>
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<tr>
<td>- Discipline</td>
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<tr>
<td>- Module</td>
</tr>
<tr>
<td>- Region</td>
</tr>
<tr>
<td>- Skill</td>
</tr>
<tr>
<td>- Topic</td>
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<td>- Type</td>
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Perhaps the most exciting part about the architecture is that it can be built out with new interfaces, for example, which have been outlined in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2: Library build-out</th>
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<tbody>
<tr>
<td>Areas identified for library build-out</td>
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<tr>
<td>----------------------------------------</td>
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<tr>
<td>● indices by region-, author- or discipline-specific resources</td>
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<td>● ability to export annotated bibliography</td>
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<tr>
<td>● applications that allow the user to track their progress through the library</td>
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<tr>
<td>● direct integration of the resource library into the Global Engineering Certificate course modules (e.g. the ability for a module to load related resources automatically within the portal)</td>
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</tbody>
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### 2.3 How classroom pedagogy informed GEI’s online architecture

#### 2.3.1 Beta 1 - An appreciation for the context of engineering practice

The portal began with a vision for an online interactive library that would house global engineering as well as engineering leadership content more broadly defined to give visitors an appreciation for the context in which 21st engineers will practice. A participatory approach was used to engage stakeholders in developing how the library material would be curated. In summer of 2014, 15 stakeholders were given access to 300 content items, and asked to evaluate and edit the suggested tagging hierarchy that had been proposed. By following an organic, participatory process, we were both able to achieve a higher level of buy-in and to develop a hierarchy that would make sense to the largest number of users. Later, a curriculum with 12 core learning modules, including both theory and skill development, was prepared for the January 2015 beta. These modules included topics such as the role of engineers in society, engineering and sustainable development, and the impact of globalization on engineering practice.

#### 2.3.2 Beta 2 - Methods for intervening within a social context

The next phase of the site will be tested in September 2015. It seeks to answer how students may learn to intervene in a social context. The appreciation for the context of engineering practice will sensitize students to the way in which they will practice as members of their discipline. We recognize that this understanding alone will not allow them to design effective interventions appropriate for the communities and contexts in which they will be deployed; Responsiveness to social context requires collaborative and consultative methodologies that take into account all stakeholders, but we believe that the basis for these skills can be effectively learned in an online context. By engaging users through a gamification environment, the platform intends to incentivize collaborative work and problem solving, while unlocking capabilities that allow them to progress through learning outcomes. The first level has been scoped from a wastewater treatment plant case study, which will challenge the user to engage key stakeholders.
Users will gain points as they identify and engage with key stakeholders and lose points if they forget to engage key players within the system.

2.3.3 Beta 3 - Toward an ethics of progressive change

By January 2016, we expect the community capabilities of the site to be fully functioning. We are aware that progressive change must be informed by a constellation of shared values, many of which are still “under construction” by young global engineers and their professors/mentors. For that reason, a critical part of the learning platform is to build community/network based learning where users can connect and discuss these ideas in real-time. This core feature allows multiple users from across the world to discuss and engage with content vis-à-vis the gamification channels built out in Beta 2.

A community architecture has been proposed that allows users to discuss and debate global engineering topics in a mediated environment. As users engage with content and modules, facilitators and mentors will pose leading questions which will facilitate desired learning outcomes. The result is an online environment which simulates group work in classroom environment, a critical tool to achieving learning outcomes (Blatchford et al., 2003).

2.4 Perspectives on learning hub development

Throughout the development process, three major challenges were identified:
1. How do we avoid the constraints of technology in order to achieve learning aims?
2. How can we empower the learner? – a challenge identified by Hill (1997);
3. How do we bottle the essence of participatory development and community engagement online?

These challenges are likely to be consistent in most online learning platform development processes. A number of measures were implemented to mitigate these challenges as noted in table 3.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Planned Solution/Best Practice</th>
</tr>
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<tbody>
<tr>
<td>How do we avoid the constraints of technology in order to achieve learning aims?</td>
<td>Pursue off the shelf/established website components that are then optimized and supplemented to meet platform needs (best practice)</td>
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<td></td>
<td>Conduct a thorough review of past online learning research and current platforms (best practice)</td>
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<tr>
<td>How can we empower the learner? – a challenge identified by Hill (1997);</td>
<td>Pursue a diverse array of learning modules that are suited to different learning styles (planned solution)</td>
</tr>
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<td></td>
<td>Develop reflective learning tools to draw user into the learning experience (planned solution)</td>
</tr>
<tr>
<td>How do we bottle the essence of participatory development and community engagement online?</td>
<td>Develop profile/community functionality that draws upon best practices from MOOCs and social networks (planned solution)</td>
</tr>
<tr>
<td></td>
<td>Bring the platform to conferences, meetings, and student events to run ‘on the fly’ design and feedback sessions (best practice)</td>
</tr>
</tbody>
</table>

With the website in its initial beta phases, it is difficult to deem whether these challenges have been successfully mitigated through our proposed solutions and best practices. Our aim is to monitor the implementation of the site using stated preference feedback from students/educators, as well as quantitative web analytics techniques to collect a robust set of feedback and data on site usage and learning outcomes.

3 CONCLUSION

The progressive values of exploration and ethical change can be said to be inscribed in the GEI’s architecture itself. The key pedagogical learning outcomes we expect in a classroom on global engineering education were not treated as independent material “helicoptered” into the curricular
modules, but rather were themselves used to develop the online GEI learning hub. Through an iterative approach over a relatively long (2-year) timeline, stakeholder and end-user involvement was maximized, which allowed us to envision a tool with widespread buy-in.

This platform is intended to continue to grow and iterate, in order to meet changing needs for sustainable development and the corresponding role engineers should play in society to meet them. While there are a plethora of existing online learning tools, there are none that are focused on enhancing engineering learning to enable engineers to play a stronger role in sustainable development in Canada and abroad. The initial development process and learning outlined in this paper shares a first attempt at meeting this need through collaboration between industry, academia, and the non-profit sector in Canada. As the platform progress it is intended to contribute to an international discourse on engineering pedagogy, either by providing a useful framework for platform development, or by continuing development to meet broader international engineering educational needs.

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References