DESIGN AND DEVELOPMENT OF AN INTERDISCIPLINARY GRADUATE PROGRAM IN ENGINEERING PRACTICE

Megan Dodd[1], Julie Conder[2], David K. Potter[3], Richard Allen[4], Salman Bawa[5], and Robert Fleisig[6]
Walter G. Booth School of Engineering Practice, McMaster University
[1]doddm@mcmaster.ca
[2]conderj@mcmaster.ca
[3]potterd@mcmaster.ca
[4]allrich@mcmaster.ca
[5]bawask@mcmaster.ca
[6]robert.fleisig@mcmaster.ca

Abstract *– In Innovation Studio, students learn how to make meaningful, creative contributions to their communities as emerging practicing professionals working on complex, multi-stakeholder problems involving elements of technology, design, business, and public policy.*

Innovation Studio builds on McMaster University's longstanding commitment to relevance through community engagement. In the Walter G. Booth School of Engineering Practice (W Booth School) in the Faculty of Engineering, we encourage our students to see not just the technical side of the international problems such as energy independence, food security and clean water, but as an opportunity to co-create change with our global and local communities for the good of all human beings, society, and nature.

Students immerse themselves in the communities in which challenges have been identified. Innovation Studio is the place and time where students bring those experiences back to the School, share their learnings and explore new ideas in a safe and familiar environment. W Booth students develop a deeper understanding of the need for empathy as they move toward a new direction or idea. Working within the context of problem identification, the teams learn how to define a project and plan an approach to produce meaningful work, prototypes, policy analysis and new enterprises.

This paper reports on the design and development of Innovation Studio as well as feedback collected from students through focus groups.

Keywords: innovation, interdisciplinarity, community engagement, leadership, design, entrepreneurship, public policy, communication, design thinking

1. INTRODUCTION

Innovation Studio is a required element of the Master of Engineering Design, Master of Engineering and Public Policy, Master of Engineering Entrepreneurship and Innovation, and Master of Technology Entrepreneurship and Innovation programmes at the Walter G. Booth School of Engineering Practice at McMaster University [1]. Innovation Studio came about as a means of providing a forum for learning related to the School's vision:

> "Creating sustainable prosperity"

and mission:

> "The W Booth School of Engineering Practice provides interdisciplinary graduate education through experiential learning and mentorship. McMaster Engineering offers a student-centred learning experience with real-world applications for tomorrow's leaders."

The Studio was developed and agreed to by the faculty of the W Booth School. In part, the vision for Innovation Studio is inspired by notions of design thinking [2] and wicked problems [3].

Students from all four degree programmes participated in this four-month long series of events and sessions in the fall of 2015 aimed at:

1. setting expectations for the degree-required project,
2. developing a sense of community at the School,
3. forming teams to work on the degree-required project,
4. learning to talk to people about real problems with an eye to addressing them with their engineering skills, and

5. fostering thought leadership amongst students.

In the remainder of this paper, Innovation Studio programming is discussed, three sample student projects are described and focus group feedback from students is presented.

2. INNOVATION STUDIO STRUCTURE

The Innovation Studio experience is unique in the field of engineering education. At the heart of the Innovation Studio concept, our students experience an in-depth creative process, which is designed to enrich their understanding and problem solving capabilities. Our students are given responsibility to choose their teams and an Innovation Challenge (i.e., a broadly defined problem that will lead to a project). The role of the faculty is to guide and coach the students towards making an innovative contribution and delivering on an outcome. Over the course of their degree, students move from selecting teams and an Innovation Challenge into three phases of studio work: discovery, definition, and delivery.

Community engagement and experiential learning [4][5] play a central role in Innovation Studio. In order to foster the conditions and sources of implicit knowledge that differentiate engineering practice from the academic study of engineering, students are required to embed their projects in local community or industry. Students learn by doing, and taking responsibility for not only technical outputs of project, but for identifying and framing the problems with stakeholders who could be clients, users, customers, investors, mentors, etc. Students are expected to identify experts and engage them as mentors or advisors to help support their project.

During the discovery stage, students develop an understanding of the needs, values, and beliefs of the stakeholders, study existing ways of doing things, and look for levers with which to advocate and create change. From the analysis of this research, a project direction is established by the students.

In the definition phase, which involves continued interaction with the stakeholders, each team explores multiple alternatives from which a project is defined. In the last phase, the team delivers on the project, whether policy alternative, new enterprise, product, process, or other implementation (or a combination of these sample deliverables). The ultimate deliverable must meet the needs of stakeholders, propose a real world implementation plan and consider organizational, business, regulatory, and policy constraints. Innovation Studio primarily supports the discovery phase of the process.

Innovation Studio meets on a regular basis and involves a mixture of time to explore ideas, analyze new knowledge, network, and interact with experts and community members. The week-by-week activities are as follows:

1. Bootcamp — Introduces the students to the School. Ice-breaker activities. Innovation Challenge themes introduced and students asked to research the theme areas of their choice.

2. Showcase — Appreciation of our community partners and showcase of the past cohort's project work to help set expectations for the new cohort. Held in a public forum.

3. Student presentations on theme research — Students critiqued on research in their theme areas.

4. Theme exploration workshop — Experts and decision makers from local community members invited to discuss their understanding of the issues and problems facing them in the theme areas chosen by students.

5. Ideation for Innovation Challenges — From research and interaction with the community, students begin to form teams around potential Innovation Challenges.

6. Innovation Challenge Presentations — Student share with other students what they want to work on for their projects. Community members are also invited to present Innovation Challenges.

7. Team and Innovation Challenge Declarations — Students select an Innovation Challenge and team, and declare themselves to the School.

8. Project Direction Workshop #1 — Students are led through exercises to help them refine their Innovation Challenge into a project direction.

9. Project Direction Workshop #2 — Continuation of the previous week.

10. Proposal Presentation Workshop — Students begin preparing slide presentation for community check-in.

11. Community Check-in Dry Run — Practice presentations and feedback.

12. Community Check-in — Students present their project direction in a public forum for feedback.

Marketing and promotion — outward facing as well as internal to McMaster University and the Faculty of Engineering — remain a key component to helping advance Innovation Studio. Various techniques are used to engage, retain and recognize stakeholders. Sample techniques include media relations, video storytelling, special events, certificates and conferences. These and other investments in high quality communication activities

help ensure that people know about Innovation Studio and its myriad benefits. It also helps ensure that key decision makers remain enthused and supportive.

3. EXAMPLES

3.1 Union Gas

Across the past decade, stakeholders have made attempts to prevent buried infrastructure from being damaged during excavations by both residential and commercial excavators. As a result, Union Gas Limited, a natural gas supplier holding valuable buried assets at risk to damage, approached W Booth School students with an opportunity to use a design thinking approach [3] to identify issues, and to provide recommendations for reducing damage costs while increasing excavation safety.

In approaching this challenge, students opted to employ a human-centred design approach [6], a process emphasizing the needs of individuals and groups requiring design, while creating personalized solutions based on stakeholder feedback. Students gathered data through quantitative methods including document review, and qualitative methods including meetings and interviews with contractors, utility providers, location service providers, and ON1CALL personnel. Using these data, students were able to create a comprehensive assessment of current practice in damage prevention, identify areas needing improvement, and provide guidelines for implementing improvement strategy.

Personal interviews with residential excavators, who only rarely need to dig, revealed dissatisfaction and frustration with both telephone and online options for requesting service. Telephone representatives were unable to solve issues without follow-up, and the existing web portal was confusing and dense with professional language. Part of this project included a redesign of the existing website, incorporating simplified instructions and fewer clicks, and a shift to online service only. Data also indicated a need to increase awareness of the necessity of contacting service providers prior to excavation. Using online and live focus groups, students identified a number of issues surrounding residents' knowledge and compliance of excavation procedure. Students then developed an effective sticker-based campaign to increase awareness by connecting stakeholders such as utility companies and hardware retailers, providing incentive for all stakeholders to participate.

Interviews with commercial stakeholders including contractors and utility providers revealed several obstacles interfering with safe excavation. A number of unsafe excavation procedures were in practice in an effort to save time, resulting in infrastructure damage. Contractors were held responsible for this damage and expressed an inability to complain about their service provider experiences. Students designed a set of recommendations including comprehensive crew training and a mobile application for use by contractors, who frequently require easy access to service providers. Students designed a functional mobile application for contractors to request service, provide location and other relevant information and education, submit reports, and provide continuous feedback directly to service providers.

Using human-centred design [6], students were able to identify a number of issues surrounding infrastructure damage that were surprising and previously unidentified, and to create a unique solution based on stakeholder needs. The recommendations included in their report, along with implementation of the developed mobile application, that will help utility providers to decrease damage at both residential and commercial levels.

3.2 District Energy

Rapidly fluctuating fuel costs and dwindling fossil fuel resources have resulted in massive changes to the energy landscape in North America over the past decade. Conventional heating and cooling systems for buildings require updating to address these changes and provide sustainable energy platforms that serve community needs.

The City of Hamilton's West Harbour neighbourhood is poised as a prime investment opportunity as it undergoes a city-led revitalization initiative. As such, it calls for the development of a state-of-the art energy efficiency technology for the heating and cooling supply to the Hamilton West Harbour Pier 7 and 8.

The student group surveyed global best practices to select a feasible, viable and desirable solution for this particular challenge. The technical, financial, environmental and social aspects of three energy alternatives to supply heating and cooling for Pier 7 and 8 were assessed. The interests of key stakeholders including city council, the provincial operators of the electrical system, the district energy firm, local real estate developers, the local university, and existing and future members of the community were taken into account.

Students evaluated available technology alternatives, analyzed emissions to regulate greenhouse gas reduction, financially compared the various alternative options, assessed the trade-offs to determine advantages over conventional power systems, and analyzed risk and sensitivity for energy alternatives.

Students narrowed down the options in a pre-feasibility report to make a 20-year value recommendation for the preferable annual costs, greenhouse gas emissions, and projected savings and profits (for both customers and plant owners), for a district combined cooling, heating and power system that uses gas turbines. The report can serve as an implementation guide for these particular technologies. This venture will affect the entire community, and will play a pivotal role in enhancing

economic, social, cultural, and recreational opportunities in Hamilton.

3.3 GEO-Market

Growing awareness of climate change has increased the prevalence and availability of knowledge on how individual choices contribute to large-scale environmental impacts. Addressing the over consumption of energy in the general public in North America is one strategy that could lead to us to a more sustainable future.

The GEO-Market project is an entrepreneurial endeavour that aims to benefit the environment, homeowners, and both local and international appliance retailers. GEO-Market is an online platform that communicates user reviews and environmental impact of specific appliances available at local retailers. Individual consumers can research appliances that are suited to reduce their long-term energy usage in their specific region, and retailers have the opportunity to increase sales by selling in bulk quantities.

The student group used a hear-create-deliver approach [7,8] to gather and analyze information and create an innovative solution to a global problem. They began by conducting interviews to identify barriers of engagement in the general public for taking action on climate change. A significant cause of decreased motivation that they identified was the volume of information available and the time required to verify and analyze evidence relevant to their individual needs. Students also communicated with local appliance retailers to identify their needs and priorities, and requirements for bulk sale appliances at reduced prices. Additionally, students developed and implemented a three-minute survey via Twitter to gather information on common practices before purchasing an appliance and their willingness to share demographic information and purchase appliances online. Throughout the design process students used an iterative approach to continually refine their project.

Students tailored their GEO-market online platform to effectively addresses a global need on an individual scale. The platform addresses a dual need for consumers to inform them on the quality and environmental impact of appliances, along with the opportunity to purchase at low-cost. The platform is likewise beneficial for appliance retailers as it offers the opportunity to sell in bulk. The GEO-market project addresses a broad challenge like climate change and incorporates social, economic and environmental aspects to invoke change through individual consumer activity on a micro-scale.

4. FEEDBACK FROM STUDENTS

Feedback from nine students midway through the program was documented with two focus-group style interviews. Conversations were recorded and anonymously transcribed, and analyzed to identify recurring themes and comments. All procedures were approved by McMaster Research Ethics Board.

Students' initial thoughts about Innovation Studio were centred around interest and excitement for an open and interactive space that would encourage social interaction and generate insightful feedback on their ideas. "It's an opportunity to see familiar faces and also to get new ideas and feedback on where you're going, you can discuss challenges and discoveries". Students were drawn to an atmosphere that would cultivate innovation in a group setting as opposed to the traditional lecture environment. As one student remarked, "it would be an opportunity to explore what I wanted to do". Some of the students with engineering backgrounds were anxious about whether their undergraduate knowledge would be fully capitalized on in the program, but many students had the impression that the hands-on nature of the program would benefit them practically in their future careers. An additional factor that drew interest was the close link to the community.

Short-term student-driven team formation activities are a major component in the early stages of Innovation Studio. Students appreciated the opportunity to get to know their peers from a diverse variety of cultural and educational backgrounds, and to experiment working with different team members prior to the final project. Though the act of team formation on short deadlines sometimes forced students to break away from their familiar groups, they felt this exposure was a good replication of teamwork in the professional environment. Students reflected on the challenges of aligning various schedules and cultural expectations. As one student noted "that's what Innovation Studio does, it gets you out of your comfort zone".

The community engagement aspect of Innovation Studio projects is a unique feature that students highly valued in comparison to their undergraduate experiences. The opportunity to form connections and interpret feedback from professionals was very much appreciated. Students noted a difference in expectations and levels of engagement between different professional and community groups that they were paired with, and sometimes felt this to be a frustrating, but valuable real-world learning experience.

The showcase aspect of Innovation Studio was clearly viewed by students to be a valuable opportunity to develop their confidence and hone their presentation skills. They felt this was a relevant skill that would contribute to success in their future careers. As an example, one student stated that "because of this [showcase] presentation I got a lot of exposure and I was able to speak confidently" at a recent meeting with an engineering consulting firm.

In-class activities were viewed by students as being a helpful exercise in translating their more theoretical training backgrounds into beneficial practical skills for the workplace. Community check-in was seen as a valuable way for students to interact with community members in a

realistic setting. As one student remarked, "I was interested to see people from the general public, because someone might say 'oh wow I'm really interested and I want to get involved'". Interaction with professors in discussion settings was also highly appreciated, and students preferred when this could be done in smaller groups.

Overall, students felt that Innovation Studio enabled them to develop valuable skills for the workplace that would not have otherwise been available in traditional Master's-level programs. The opportunity to work in teams; to deliver presentations and articulate their ideas; to work with professionals and to network and form strong friendships through their projects was viewed very positively. As one student remarked "Sometimes you think you have all the ideas and it still blows my mind to see what other people are thinking, and this experience gives you the edge to work more with teams". Overall, students felt they will take forward a number of practical and professional skills from this experience to their future careers.

5. CONCLUSIONS AND RECOMMENDATIONS

Innovation Studio provides a unique experience in the field of engineering education. By working with complex real-world problems as Innovation Challenges, students develop the ability to approach engineering tasks viewing each problem universally and multi-dimensionally. Solving problems through the stages of discovery, definition, and delivery, Innovation Studio graduates develop creativity and practical skills for use in their careers.

The examples provided here indicate that students have developed the ability to identify issues involved in their Challenge, think critically from multiple perspectives to create a unique solution, and provide a guide for implementation of the solution to best fit multiple stakeholder needs. Community involvement throughout the process allows students to gain valuable insight, experience, social opportunities, and connections to local industry.

Student feedback indicates that students enjoy working with real stakeholders in the community and desire even more interaction with them. This includes having increased stakeholder involvement in projects, mentorship, and having stakeholders present views through interviews and guest lectures.

While Innovation Studio provides an invaluable opportunity for skill development, its methods may be surprising or intimidating to students unfamiliar with frequent teamwork and presentation. Similarly, the lack of traditional course structure and expectations may cause initial anxiety for students. Student recommendations for program development include increased structure, development of internship opportunities, and expanded interdisciplinary involvement on campus.

W Booth School looks forward to expanding Innovation Studio. Increasing diverse options for Innovation Challenges by strengthening community involvement and continuing to attract the highest calibre of local and international engineering students will ensure the continual growth and improvement of the program.

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