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Developing engineering leadership skills through student-led workshops in the context of engineering grand challenges

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CONTEXT
Strong leadership skills and an understanding of the engineering role in both technological innovation and stewardship are required to address global problems such as the grand challenges. Incorporating leadership skills development and connecting leadership to a broad awareness of socio-technical responsibilities can be complex in what is a very full engineering curriculum. This study describes the creation of co-curricular student-developed and led online workshops as a mechanism to provide engaging and broadly accessible experiential learning activities to address this learning opportunity.

PURPOSE OR GOAL
Through this work, we look to demonstrate that student-developed and led online workshops can effectively and efficiently provide experiential learning opportunities that can build knowledge, skills and attitudes related to leadership development and technological stewardship. Ultimately the goal is to demonstrate an effective and efficient methodology for student engaged learning that can be incorporated in the engineering curriculum.

APPROACH OR METHODOLOGY/METHODS
Undergraduate engineering students created and led 90-minute online workshops that combine leadership skills development (e.g., exploration of values, domains of influence) and an introduction to the Canadian Engineering Grand Challenges (CEGC) such as "Inclusive, safe, and sustainable cities". Workshops are delivered to students at Canadian Engineering schools in February and July (and November 2021 forthcoming). At each workshop, qualitative and quantitative survey data is collected from the participants related to engagement in the learning experience, development of leadership skills, and the relationship to CEGC. The methodology used and resources required to ensure that students create relevant, aligned workshop material is also documented.

ACTUAL OR ANTICIPATED OUTCOMES
The first workshop (February 2021) was delivered to engineering students at two institutions. The second workshop (July 2021) was delivered to engineering students from 4-6 institutions. Preliminary results show high engagement during the workshop, increased awareness of personal leadership development, and strong awareness of the CEGC and their relevance to engineering leadership. The participant survey results from the first two workshops will be analysed. The third workshop (November 2021) will involve engineering students from institutions across Canada.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY
Preliminary results indicate that student-led development and delivery of co-curricular workshops are efficient and effective for student learning. Student participants were highly engaged in leadership development and readily connected the concepts to engineering grand challenges and technological stewardship. This shows promise as a methodology for providing access to learning opportunities that are flexible, scalable, and broadly accessible. A next step recommendation is to explore the integration of this methodology into existing curriculum, creating opportunities to enable student engagement in their own learning.

KEYWORDS

Engineering Leadership, Experiential Learning, Lifelong Learning

Background

Strong leadership skills and an understanding of the engineering role in both technological innovation and stewardship are required to address global problems such as the grand challenges. The “grand challenge” concept started as the unsolved problems in mathematics in the early 1900s, and today is an approach used to focus and inspire professions to reflect on and approach problems of deep societal importance. Incorporating leadership skills development and connecting leadership to a broad awareness of socio-technical responsibilities can be complex in what is a very full engineering curriculum. Supported by the Engineering Deans of Canada (NCDEAS, 2019), the Canadian Engineering Grand Challenges (CEGC) are global but have a uniquely Canadian context. The CEGC provide an opportunity to use the grand challenges as a framework and to develop the student mindset by developing expertise and leadership to bear new ideas and reimagine solutions. This study describes the creation of co-curricular student-developed and led online workshops as a mechanism to provide engaging and broadly accessible experiential learning activities to address this learning opportunity.

Needs and Objective

The engineering education culture is experiencing a shift in context for engineers, with a growing need for leadership and management skills to complement technical knowledge. Leadership skills development needs to be part of the educational content and the engineer’s mindset (Jamieson and Donald, 2020). Engineers have a desire to develop sustainable solutions to large complex problems, and in sustainability, and would benefit by having targeted training to address socially-motivated problems that inherently require an understanding of multiple perspectives and disciplines (NCDEAS, 2019). The cultural approach to engineering education is shifting to incorporate socio-technical requirements into curriculum (Martin and Polmear, 2021). Currently, important skills such as leadership, ethics, and reflective practice required for lifelong learning are under-represented in the curriculum given this new cultural context. Incorporating these skills is complicated by an already-packed curriculum. The objective of this paper is to present an innovative process of engaging students in the CEGC to help educate future technology leaders and stewards to critically reflect on the important role they play in transforming our world. Co-curricular student workshops have been growing as a means to address this leadership learning opportunity (e.g., “Troost ILead” n.d.; “Schulich Engineering Leadership Program” n.d.), however the concept of student-developed and led workshops is rare or missing. Specifically, the authors explore this opportunity and learning potential.

Through this work, we look to demonstrate that student-developed and student-led online workshops can effectively and efficiently provide experiential learning opportunities that can build knowledge, skills and attitudes related to leadership development and technological stewardship. Ultimately the goal is to demonstrate an effective and efficient methodology for student engaged learning that can be incorporated in the engineering curriculum. This is important for three main reasons:

- Student engagement in creating their own learning experiences, that is autonomy-supportive pedagogies (Goldberg and Somerville, 2014, 159–62), can be transformative and support life-long learning.
- Mechanisms to address challenging curricula and introduce socio-technical concepts are often missing.
- Success may influence the inclusion of curricular activities in existing programming, from an engineering mindset/content (i.e., socio-technical and CEGC) and methodology (i.e., students teaching students) perspectives.

Student Learning – Experiential and Online

Students see a need for experiential learning opportunities and leadership skills development. At its core, experiential learning follows Kolb's learning cycle comprising: experience – reflection – conceptualization – experimentation (Kolb, 1984). The need and opportunity for students to be engaged in the development of their own learning (Goldberg and Somerville, 2014) inspired our approach towards "for students, by students" in which students developed and led workshops for other students. Learning activities and materials, adapted to an online environment, were designed to draw on abilities from each stage of the process, in sequence, for knowledge construction. This "hands-on learning" for leadership development in virtual environments, which simultaneously helped build digital competency, is a new area to explore. Experiential learning outcomes related to student engagement in their own learning, and student motivation by exposure to the CEGC framework inspire their respective professions and influence their learning.

Leadership Mindset

A review of engineering leadership education suggests six key competencies emerging: communication, innovation, creativity, execution, personal drive, and teamwork (Paul, 2015); while the National Academy of Engineering (2004) emphasized leadership in the "Engineer of 2020", and the "Whole New Engineer" emphasizes leadership and the creative imperative (Goldberg and Somerville, 2014). To inspire curricular change initiatives to address these leadership competencies in the context of sustainability, two special interest groups (SIGs) have emerged in the Canadian Engineering Education Association (CEEA-ACEG). The "Engineer of 2050" and the "Sustainable Engineering Leadership and Management" SIGs facilitate discussion on the identity and attributes of the engineers of the future, who will both shape and respond to future global trends. Focusing on engineering leadership at the intersection of the human and technical requirements brings effective and sustainable operation of these complex systems in our world. Leveraging the CEGC as an application framework will greatly test students as there are no obvious solutions and will require abstract thinking, creativity, and systems thinking to build new competencies. The CEGC framework can also help to emphasize the high relevance of these skills in parallel to the traditional emphasis on technical skills.

Technological Stewardship

By definition, "Technological stewardship is behaviour that ensures technology is used to make the world a better place for all — more equitable, inclusive, just, and sustainable. To accomplish this, technological stewardship calls on those who create and influence technology to step into a responsible leadership role" (Canadian Federation of Engineering Students, 2018). At its core, this definition is also a call to action to students and professionals in technology-related fields to demonstrate leadership at an individual and societal level in addressing the technological needs of their community, all the while continuing to coexist with nature, and increasingly relevant because technology continues to evolve at an incredibly fast pace.

As the focal point of engineering shifts from the technical into the socio-technical realm it drives the need for changes in engineering education to develop technology stewards by advancing new competencies and developing leadership skills. Technology stewards are people with experience of the workings of a community to understand its technology needs, and experience with technology to take leadership in addressing them. Technological Stewardship principles are (Engineering Change Lab 2019):

- **S**eek purpose
- **T**ake responsibility
- **E**xpand involvement
- **W**iden approaches
- **A**dvance understanding
- **R**ealize diversity
- **D**eliberate values
- **S**hared action

Grand Challenges

The made-in Canada version, Canadian Engineering Grand Challenges, reflect the unique characteristics of Canada and the Canadian engineering education landscape. The CEGC are rooted in the United Nations' 17 Sustainable Development Goals (SDG), which represent the world's call to action to address the challenges and opportunities facing the world and humanity. For the community of engineering educators, considerations about how engineering education might evolve to prepare our students for the many opportunities and challenges that society will face in 2030, 2050 and beyond, are now pressing, and prompting action. The coming decade is the "decade of action" to expedite efforts to meet the global targets for the SDG. Engineers with strong technical skills sufficiently addressed the needs of society in the past century, however, challenges of the 21st Century and particularly the coming decade require both engineering expertise and leadership, in which for example, sustainability in design requires an engineering mindset that incorporates leadership and a view toward technological stewardship. Embedded in future-thinking to reimagine engineering education, the scope of this study leverages the six CEGC (NCDEAS, 2019):

1. Resilient infrastructure,
2. Access to affordable, reliable and sustainable energy,
3. Access to safe water in all communities
4. Inclusive, safe, and sustainable cities,
5. Inclusive and sustainable industrialization, and
6. Access to affordable and inclusive STEM education.

Methodology

The methodology used and resources required for the workshop development "by students, for students" to develop leadership skills in the context of the engineering grand challenges is presented in this section. Undergraduate engineering students created and led 90-minute online workshops that combine leadership skills development (e.g., exploration of values, developing vision, enabling others) and an introduction to the Canadian Engineering Grand Challenges (CEGC) and technological stewardship principles. Workshops were delivered to students at Canadian Engineering schools in February and July 2021, with a third workshop in November 2021 forthcoming. At each workshop, qualitative and quantitative survey data is collected from the participants related to engagement in the learning experience, development of leadership skills, and the relationship to CEGC.

General learning outcomes include: 1) building awareness on the CEGC, 2) developing leadership skills, and 3) leveraging online learning spaces for experiential learning opportunities. Demonstration of these learning outcomes is used to assess development stages of leadership skills and leadership identity, ability to interpret the importance and relevance of CEGC, and engagement of experiential learning activities online. Assessment of the learning outcomes will be analysed and reported in a future publication.

Phased Approach to Workshop Development and Delivery

The development team envisioned a series of workshops that could be applied in local and national contexts, grow in institutional reach, and deepen in CEGC focus as experience was gained in the workshop development and delivery process. This resulted in convening and supporting the delivery of three online workshops in a phased approach, as follows:

- firstly, to students within the two participating institutions,
- secondly, to students recruited through the members of the Canadian Engineering Education Association (CEEA), and

- finally, to students in the wider Canadian engineering education community as a pan-Canadian culminating “Leadathon” event.

Workshop Development

A key element for our success in this process was to hire undergraduate students to lead the process as the core student team to develop and deliver the workshops. In this case, the student team consisted of 3-5 co-op (co-op consists of multiple academic terms and multiple work terms) students over the course of two semesters (Jan-April 2021 & May-Aug 2021) who worked on the workshop development as part of their duties. The total work was the equivalent of approximately 1.5 FTE (0.5 at Waterloo, 1.0 at Guelph).

To complete the workshops, the core student team had or developed the following prerequisite knowledge:

- Constructive alignment with Bloom’s taxonomy
- Engagement in the CEGC, sustainability concepts, technical stewardship principles
- Experience in delivering workshops

The workshop development steps and cycle followed for each of the three workshops are shown in Figure 1.

Figure 1: Workshop Development Cycle

Content Development

The student-led content development included iterative steps, summarized as follows:

1. Brainstorm/Reading Literature: To familiarize with literature and resources.
2. Professor Mentorship: To guide and support students along their learning journey.
3. Refine Content and Select Focus: To narrow the scope to accommodate durations.
4. Lecture and Activity Creation: To build workshop material and hands-on activities.
5. Rehearsal and Revisions: To gather feedback and improve the learning experience.

The base content included four main topics, and a discussion on values as a starting point in each workshop. The topics include: Technological Stewardship, UN Sustainable Development Goals, Triple Bottom Line, and Canadian Engineering Grand Challenges.

Facilitator Selection/Training

The core four-student team, with support from faculty members, underwent a process to recruit student facilitators through an application process where applicants articulated their motivation and interest in engineering leadership and their attitude to support serving as facilitators at the workshop. Selected facilitators were invited to a “train-the-trainer” session delivered by the core team on content, online tools and facilitation techniques. Facilitators were also given an orientation to the workshop content, including a practice run; and training in the online tools for workshop delivery, such as the use of breakout rooms and shared documents such as *Google Sheets;* and practised facilitation tips to engage participants,

interact with others, and drive discussions. The outcome of this stage is to define the roles of the facilitators and the timing of workshop activities, in addition to identifying the resources required for running workshops (eg. determine facilitator to participant ratios).

Event Promotion and Participant Recruitment

Workshops were promoted by the core student team through an outreach effort on social media (e.g., *LinkedIn*, *Instagram*), student societies, and faculty networks at the partner institutions, such as the CEEA-ACEG membership. Working with the CEEA-ACEG network was effective in reaching a wider student participation from universities across Canada. To facilitate the registration process for participants from multiple institutions, the core student team also developed the expertise to use online registration tools such as *eventbrite*.

Workshop Delivery

The 90-minute workshop delivery follows a structured format that starts with a discussion of values and the motivation of engineering as a leadership profession. Following this, there is an introduction to the main content theme, followed by a series of content and breakout room activities, and closing with a summary and a key takeaway session. The workshop was intentionally structured to provide a mix of new material and large group reflection in the main room content, small group interaction and in-depth discussion in the breakout room activities.

The general model for the workshop structure is:

1. Introduction (10 minutes)
2. Breakout Room Introductions (5 min)
3. Main Room Content (20 min)
4. Breakout Room Activity #1 (10 min)
5. Main Room Content (20 min)
6. Breakout Room Activity #2 (10 min)
7. Closing and Key Takeaways (15 min)

Workshop Assessment

Upon the conclusion of the workshop, a follow-up survey is sent to the participants (and facilitators in the July workshop). Workshop assessment includes qualitative and quantitative survey data collected from the participants and related to engagement in the learning experience, development of leadership skills, and the relationship to CEGC. The survey distributed to participants also includes general questions about institution, year of study, engineering program, and gender. Participant survey questions are listed in Appendix A.

Observations/Results

The observations and results focus on the development and delivery process for the two workshops delivered. The participant survey results from the workshops and feedback from the faculty observers will be analysed upon the conclusion of the third workshop. The first workshop was delivered in February 2021 to 114 engineering students at two institutions. Preliminary results show high engagement during the workshop, increased awareness of personal leadership development, and strong awareness of the CEGC and their relevance to engineering leadership. The second workshop was delivered in July 2021 to 39 engineering students from 9 different institutions. Canada has 45 institutions that deliver accredited engineering programs (Engineers Canada, 2019). In addition, including the principal investigators, faculty observers from six of institutions also attended the July workshop. The third workshop will involve engineering students from institutions across Canada and take the form of a “Leadathon” where engineering students will work to address selected CEGC.

Based on the first two workshops offered, there are some preliminary observations regarding the workshops include student interest and perception, and faculty interest and motivation.

The distribution of student participation was spread relatively evenly across all levels, from year one through graduating years in engineering programs. Student perceptions of the quality of both the workshop delivery, content and learning were quite high, providing a rating of 4.3/5 for meaningfulness, and 4.2/5 for applicability. Two quotes from participants serve to demonstrate the effectiveness of the workshop:

> *"What I learned from this workshop is that there are two sides to every story. To be an effective leader you must take the time to understand both sides to see the entire picture… a leader should seek to comprehend the benefits and consequences then compare the risk of both sides before coming to a conclusion. – Participant from February workshop*

> *"[The leadership skills developed include] thinking quick, creatively, critically, and profoundly to map CEGCs; explaining and justifying my personal recommendations/thoughts in the breakout sessions, while also listening to others." – Participant from July workshop*

Faculty observers at the second workshop indicated in follow-up conversations that they were highly inspired to engage their students in broader societal challenges, and most notably expressed an interest in collaborating to develop a similar leadership learning approach at their own institutions.

Table 1: Summary of Workshops

	Workshop 1 (Waterloo-Guelph)	**Workshop 2** CEEA	**Workshop 3** Pan Canadian Leadathon (planned)
Timeline	February 2021	July 2021	November 2021
Core student team	4	4	4
Number of institutions	2	9	>10 (target)
No. of participants	114	39	>60 (target)
No. facilitators	18	16	>10 (target)
Duration	90 minutes	90 minutes	3.5-4hrs
Content	Tech Stewardship UN SDG CEGC	Triple Bottom Line CEGC Tech Stewardship	CEGC Tech Stewardship
Activities	Debate on new technology, CEGC prioritization	Concept maps of CEGC and Triple Bottom Line, and Tech Stewardship	Concept maps of CEGC, SMART Goals, Milestone plans, adaptive leadership
No. of breakout rooms	9	7	TBD
Survey response rate	90%	23%	TBD

Analysis and Discussion

An analysis of the impacts on students, facilitators and faculty shows engagement in the workshop development and delivery process on several levels. The core student team, student participants, and student facilitators learning experience demonstrates a desire to go beyond technical knowledge and connect the social context to engineering solutions. The workshop development follows a pedagogical model that emphasizes learning outcomes and utilizes teaching tools and approaches (e.g., concept maps, debates) to embed and strengthen learning in group activities.

The quality and effectiveness of the process was evidenced by our ability to plan, develop and deliver workshops in a compressed timeline, including the outreach for selecting and training facilitators and recruiting participants. The outreach effort and engagement of participants from other institutions was facilitated by faculty across the country and helped promote nationally and was complemented by the core team of students who recruited through their own national networks of student societies. The facilitation carried out by students was a critical success factor in providing greater comfort and engagement of

participants in breakout sessions and in large group reflections, in addition to peer mentorship experience during the “train-the-trainer” sessions. A continuous improvement process is made possible due to the iterative nature of workshop development and the phased approach to workshop delivery across Canada, also recognizing the meaningful observations from faculty observers. Another critical success factor was the enabling environment in which the core-student team operate within that leverages their experience with the Guelph Engineering Leadership (GEL) program and the UWaterloo’s Student Leadership Program.

There is a difference in attendance between the first and second workshops, that may be attributed to the February workshop being held as part of a leadership certificate during the academic year, whereas the July workshop was a one-off independent workshop during the traditional summer break period across most of the participating institutions. In both cases, the unique aspect about this learning model is the self-enrolment which rests on student’s own motivation, unlike curricular courses which are mandatory for credits. The participation was generally above our target numbers, with a diverse (across undergraduate years, engineering discipline, and gender) participation across Canada from “coast to coast” as a benefit of the online delivery.

Conclusions and Recommendations

Preliminary results indicate that student-led development and delivery of co-curricular workshops are efficient and effective for student learning. Students were highly engaged in leadership development concepts and readily connected the concepts to engineering grand challenges and technological stewardship. This methodology is promising for providing access to relevant intentional learning opportunities that are flexible, scalable, engaging and broadly accessible. A next step is to explore the integration of this methodology into the traditional curriculum, creating opportunities to enable student engagement in their own learning. The team is exploring the development of online modules, and experiential learning case studies, in addition to toolkits and facilitator guides to encourage wider application of the leadership skills related to the CEGC and technological stewardship principles, and adoptions by institutions delivering online learning inclusive of various Learning Management Systems. Recognizing the high impact of experiential learning, a more ambitious recommendation calls for finding creative ways to include skills such as leadership, ethics and reflective practice required for lifelong learning into existing engineering curricula and connect to graduate attributes (e.g., regulated by the Canadian Engineering Accreditation Board) to address the needs for incorporating these currently under-represented, 21st Century skills in an already-packed curriculum.

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References

Canadian Federation of Engineering Students. 2018. “Engineering Change Lab 11 and 12.” 2018. Retrieved August 2, 2021.https://cfes.ca/blog/2018/11/engineering-change-lab-11-and-12/.

Engineering Change Lab. 2019. “Technological Stewardship Principles for the Engineering Community.” Retrieved August 2, 2021. https://www.engineeringchangelab.ca/wp-content/uploads/2019/07/Draft-Technological-stewardship-principles.pdf.

Engineers Canada. 2019. “Canadian Engineers for Tomorrow - Trends in Engineering Enrolment and Degrees Awarded 2015-2019.”

Goldberg, D.E., and M. Somerville. 2014. *A Whole New Engineer: The Coming Revolution in Engineering Education*. Threejoy Associates, Incorporated. https://books.google.ca/books?id=VK_toQEACAAJ.

Jamieson, Marnie, and John Donald. 2020. “Building the Engineering Mindset: Developing Leadership and Management Competencies in the Engineering Curriculum.” *Proceedings of the Canadian Engineering Education Association (CEEA)*, June. https://doi.org/10.24908/pceea.vi0.14129.

Kolb, D. A., 1984. Experiential learning: Experience as the source of learning and development, Prentice Hall, Englewood Cliffs NJ.

Martin, Diana Adela, and Madeline Polmear. 2021. “The Two Cultures of Engineering Education: Looking Back and Moving Forward.” In *Engineering and Philosophy: Has Their Conversation Come of Age?*, preprint, (Eds.) Hyldgaard Christensen, S., Buch, A., Conlon, E., Didier, C., Mitcham, C. & Murphy, M. Springer Nature, Vol. Philosophy of Engineering and Technology.:16.

National Academy of Engineering (NAE), 2004. The Engineer of 2020: Visions of Engineering in the New Century. National Academies Press, Washington, D.C.

National Council of Deans of Engineering and Applied Sciences (NCDEAS), Canadian Engineering Grand Challenges (2020-2030): Inspiring Action to Improve Life for Canadians and the World, Sherbrooke, QC, Nov. 2019.

Paul, R.M., 2015. Engineering Leadership Education: A Review of Best Practices, American Society of Engineering Education

“Schulich Engineering Leadership Program.” n.d. Schulich School of Engineering. Retrieved August 2, 2021. https://schulich.ucalgary.ca/current-students/undergraduate/launching-your-career/engineering-leadership-program.

“Troost ILead.” n.d. Troost Institute for Leadership Education in Engineering. Retrieved August 2, 2021. https://ilead.engineering.utoronto.ca/student-programs/.

Appendix A

Workshop Assessment survey questions and response formats:

Question	Response Format
On a scale of 1-5, how relevant was this workshop to your leadership development?	Linear scale; 1= Very Irrelevant, 5 = Very Relevant
How important are these topics in your leadership development (Triple Bottom Line, CEGC, Technological Stewardship)?	Linear scale; 1= Not Very Important, 5 = Very Important
List 3 leadership skills or ways that you developed your leadership through this workshop.	Long answer
Which of Canadian Engineering Grand Challenges do you think should be addressed first? (List of 6 CEGC)	Multiple choice selection
Describe why you think this challenge should be addressed first.	Long answer
I found this online workshop engaging.	Linear scale; 1 = Strongly Disagree, 5 = Strongly Agree
I would be interested in attending another workshop or working through an experiential learning module on similar topics.	Linear scale; 1 = Strongly Disagree, 5 = Strongly Agree
What did you like best about this workshop?	Long answer
What suggestions to you have for improving the workshop?	Long answer
Do you have any other comments or feedback?	Long answer

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