Pivoting Engineering Entrepreneurship Education Following the COVID-19 Pandemic

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Abstract – The spread of COVID-19 has significantly disrupted the educational landscape since March 2020. Instructors at higher education institutions had to quickly transition to an online environment for remote delivery of their academic programs. Even though academic programs are relatively easy to adapt for remote delivery as compared to other industries, educators were still tasked with redesigning their courses to guarantee the quality of education delivered to their students.

This challenge is particularly true with engineering entrepreneurship educators since their course structures heavily focus on developing intangibles such as an entrepreneurial mindset and team collaboration through immersion into hands-on learning experiences. To create this experiential learning environment, engineering entrepreneurship educators have, in general, relied upon face-to-face interactions with students. Little has been published in the existing literature to report the challenges, strategies, and innovations that can help transition effectively and deliver such academic programs remotely.

In this paper, the authors from four major Canadian higher education institutions report our experience from ‘trial-by-fire’ mode to redesign and deliver various courses for remote learning. This paper is by no means presenting validated “best practices” but aims to trigger discussions surrounding tools available to educators considering such a transition. We hope that this paper will provide insights and strategies for our colleagues to employ in their future course design and delivery. We also hope to invite a conversation to learn more about our colleagues’ experiences and explore opportunities to identify and validate approaches for effectively teaching engineering entrepreneurship in a remote learning environment.

Keywords: Engineering, Entrepreneurship Education, Online Education, Student Engagement, Student Performance, COVID19

1. INTRODUCTION

The global spread of COVID-19 has significantly changed the higher education landscape in unforeseen ways. Since the World Health Organization (WHO) declared the worldwide pandemic in March 2020, most Canadian universities quickly transitioned all their course offerings online. This form of delivery remained throughout the 2020-21 academic year. Online education and remote learning enabled universities to continue providing knowledge and skills training to their learners. However, this is a new frontier for engineering education, especially in engineering entrepreneurship [1].

Before the pandemic, despite the popularity of Massive Open Online Course (MOOC) platforms—such as Coursera, edX, and Udacity—the adoption of online delivery for degree-granting programs remained low [2]. While online engineering entrepreneurship education is not novel, it has yet to gain broad support mainly because of the unique learning requirements of contemporary pedagogical approaches emphasizing hands-on practice, real-world immersion, and experiential learning [3][4]. We also have minimal prior experience delivering entrepreneurship education online in degree-granting institutions. For example, entrepreneurial skills such as performing market research, conducting interviews, and designing and developing a product require hands-on practice [5]. Such learning outcomes are also difficult to assess online in a cost- and time-effective way. Student engagement and social interaction can also be challenging due to the lack of face-to-face contact and more infrequent feedback from their instructors [6].

The pandemic has motivated us, the engineering educators, to practice what we preach to our students: to be adaptive, agile, and creative. It has also reminded us that we do not yet fully understand the best tools and methods to teach engineering entrepreneurship in an online environment.

In the following work, we report four different approaches in delivering entrepreneurship education in four Canadian universities based on our interviews with the instructors. We present the context surrounding the courses, the delivery methodology and tools used to deliver the content, and the tools and methods used to engage with students. We also explore the outcomes for students in terms of their performance based on the same or similar rubrics used before the pandemic. We hope to initiate a conversation around online entrepreneurship training to improve our practice collectively.
2. LITERATURE REVIEW

Distance education is not novel. Many institutions and disciplines have attempted to offer classes online to more rural and remote student populations. However, the innovations and new technological platforms in engineering education were never widely adopted [7][8]. Online course enrollment represents approximately 16% of all course enrollment in Canadian universities, while the most frequently offered courses are business, education, and health [9]. Statistically speaking, the adoption rate in engineering entrepreneurship education is even lower.

There are many reasons for not adopting such innovations and new technological platforms. The organizational culture, for example, has been identified in previous studies to be one of the obstacles [8]. However, this was no longer relevant since the pandemic forced all institutions to transition their program offerings online. Still, the pedagogical considerations are more challenging for educators to address.

Previous studies have shown online education to be effective and to offer similar outcomes as on-campus programs measured by test scores [6]. It is worth noting that such studies focused on the courses that had been adopted online. Most of the already adopted courses tend to be more content-focused and work well with a teacher-centric pedagogy approach such as Perennialism or Essentialism [10]. Engineering education typically requires a student-centric approach to facilitate an emphasis on practice. Specifically, engineering entrepreneurship education is both a science and an art, where the former relates to the functional skills required for business start-up (e.g., accounting, economics, and marketing), while the latter relates to the creativity and integration of diverse skills and perspectives [11]. To ignite the innovative and creative elements of entrepreneurship, courses often employ a student-centric progressivism pedagogy, where the need for face-to-face interaction and experiential learning is high [5][12]. The contemporary approaches for engineering entrepreneurship education emphasise hands-on practice, real-world immersion, and experiential learning, which can account for most classroom time [1].

Therefore, at the beginning of the pandemic, most educators experienced difficulties in delivering their courses designed to be offered in a face-to-face environment due to the lack of resources and training in online teaching. Furthermore, many educators questioned the viability of teaching and training an entrepreneurial mindset and entrepreneurship practice online.

In response to COVID-19 and the requirement for delivering engineering entrepreneurship education online, educators researched and employed many innovative teaching methods and technological tools developed by different providers. Communication and collaboration tools developed by private companies were also investigated and applied in educational settings to provide better experiential learning experiences.

Transferring all learning processes to a remote learning environment requires redesigning learning processes initially designed for the physical classroom. Based on the literature and the authors’ experiences, redesigning engineering entrepreneurship education for online delivery should address the following areas, and therefore, needs to overcome the challenges associated with them.

2.1 Digital Tools and Network Infrastructure

One challenge comes with the very digital tools making online education possible. Because the current redesign and transition efforts were unplanned, educators needed to rely on digital tools that were not initially designed for higher education institutions. As a result, educators needed to select from a diverse range of available tools based on personal experience and limited IT (information technology) support [13]. Educators also needed to ensure that students were familiar with the digital tools and their functionalities to guarantee the effective exchange of knowledge.

Another challenge is poor network infrastructure in rural areas in Canada or developing countries [14]. Furthermore, the new reality of working from home in nearly all industries puts pressure on the network infrastructure, particularly for students who share accommodation with other students or parents who also depend on a stable Internet connection to complete their work. Instructors needed to offer strategies to provide equitable access to all students enrolled, regardless of their access to high-speed Internet [15].

2.2 Virtual Lecture Delivery and Instructor’s Role

Even though there are many digital tools available for online communication, online education presents many unique challenges compared to regular face-to-face interactions. For example, instructors struggle to interpret the students’ verbal and non-verbal cues in a virtual remote environment as they would do in the classroom [16]. Therefore, it becomes difficult for instructors to provide timely feedback to students. The same applies to instructors since they can no longer use body language or facial expressions to convey messages in a virtual environment. The “voice” becomes the most critical tool instructors rely on [17].

Educators may increase accessibility for students by using synchronous and asynchronous communication strategies. While synchronous strategies may provide a similar interaction and opportunity for timely feedback,
asynchronous delivery allows access to lecture content at a time convenient for the student, especially relevant to those who may live in a different geographical location and time zone [18].

The instructors may also need to adapt their roles to become a coach and mentor as the teacher is no longer physically present in the students’ learning. As such, courses need to shift from a teacher-centric to a student-centric approach. In this new approach, the instructor needs to take the role of a facilitator who guides the student’s learning process instead of knowledge transfer [16].

2.3 Experiential Learning

Engineering entrepreneurship education requires real-life immersion and hands-on experiential learning [19]. It is challenging to provide high-quality, real-life experiential learning in a virtual environment. Instructors need to provide support for students to collaborate in teamwork and engage in peer feedback and learning [20]. Furthermore, instructors should build on their facilitator role [21] to engage and facilitate frequent communication and discussions. They should provide clear instructions and support to enable team discussion, collaboration, and conflict resolution. These are critical for increasing student motivation and achieving learning outcomes.

2.4 Engagement and Community

One of the less discussed areas of online education is student motivation and engagement. The success of the redesigned virtual education depends on students’ willingness to use the available tools and strategies set by the instructors [22]. It is essential to ensure that students are engaged and emotionally connected to the course [23]. However, the lack of regular face-to-face interactions may make it challenging to build a long-lasting emotional connection between instructors and students. Strategies are needed to develop rapport between instructors and students and motivate student participation. It is also essential to build a community for students to engage in peer learning [24][25]. An active community is also key to reducing stress and potential mental health issues for students amplified under the uncertainty surrounding the pandemic.

2.5 Assessment

Assessment is crucial to measure the students’ competency to meet the 12 graduate attributes defined by the Canadian Engineering Accreditation Board (CEAB). In a virtual and remote environment, instructors need to determine specific and measurable goals and expectations and periodic evaluations to provide more frequent feedback. For content and knowledge-focused courses, instructors need to ensure academic honesty. For the more experiential and team-based courses, instructors need to ensure appropriate assessment of decision-making processes and other criteria [26].

2.6 Prototyping (Design Only)

For the design- and development-focused courses, prototyping is another challenge. Students cannot meet in-person to collaborate and develop a physical model. Software and hardware integration may also be challenging. For students who live in widely spread areas such as in rural Canada, this challenge might be even more difficult to overcome. Students may live hundreds of kilometres away from each other, making it extremely difficult to share prototyping workload equitably. Furthermore, students may require access to advanced manufacturing tools such as a CNC machine, 3D printer, or welding machine that are not available outside of campus facilities.

3. AN ENTREPRENEURIAL RESPONSE

This section illustrates the challenges experienced and strategies employed by the authors to redesign their entrepreneurship programs by leveraging digital technologies. We will show new approaches to delivering the educational contents and to creating student engagements in four universities: Memorial University of Newfoundland (MUN), University of Saskatchewan (USask), University of New Brunswick (UNB), and University of Waterloo (UW). In

Table 1, our results covered courses at both undergraduate- and graduate-level of study, including courses such as Engineering Economics, Product Design and Development, Technology Management, and Venture Creation.

3.1 Courses Presented in This Paper

Engineering Economics is an introduction to determining the economic feasibility of engineering projects; time value of money (interest rates, depreciation, annual, present and future worth analysis); benefit-cost analysis, tangible and intangible benefits and costs; and economic optimization. The course also introduces project management techniques, including planning, scheduling, and project controls.

Technological Innovation Design and Product Design and Development are senior design capstone courses. In the senior design capstone course, students work collaboratively to investigate and define a problem and the needs related to the problem. Students then work collaboratively to conceive, design, build, and test a solution to solve the problem by satisfying the related needs. The design capstone course is the pinnacle of undergraduate education and a unique first step to
engineering entrepreneurship. The course is also offered at UNB as a graduate course.

Table 1 Course Collection and Subject Matters

| Institution                | Course Subject                  | Level of Study  |
|----------------------------|---------------------------------|-----------------|
| Memorial University of Newf| New Venture Creation             | Undergraduate   |
| Land                       | Engineering Economics           | Undergraduate   |
|                            | New Venture Creation            | Undergraduate   |
| University of Saskatchewan | Engineering Economics            | Undergraduate   |
|                            | Technological Innovation Design | Senior Capstone |
|                            | Technology Innovation Management| Undergraduate   |
| University of New Brunswick| Product Design and Development  | Senior Capstone |
|                            | Product Design and Development  | Graduate        |
| University of Waterloo     | Foundations of Venture Creation | Undergraduate   |
|                            | Foundations of Venture Creation | Undergraduate   |
|                            | Foundations of Venture Creation | Undergraduate   |

New Venture Creation at MUN covers the essential aspects of the entrepreneurial process (new business creation). That is, the iterative process (lean start-up approach) that starts by recognizing a business opportunity (problem), followed by conceiving a business idea (solution), assessing the idea, developing a business model, and ending by launching and then growing a sustainable business.

Foundations of Venture Creation at UW is similar to New Venture Creation taught at MUN, with an emphasis on experiential learning. The course design includes two separate student venture pitch competitions organized as campus-wide events each term and weekly one-to-one coaching sessions with a network of alumni start-up business founders.

Technology Innovation Management is a course that focuses on strategies required to manage new technologies. The course serves as a foundational course to determine the commercialisation potential of the new technology. The course introduces tools such as S-Curve to access the state of technology development, the tools to protect a new technology such as intellectual properties and trade secrets, and strategies to organize and manage the product development team and process.

3.2 Trial by Fire – A Swift Response

Back in March 2020, when all institutions swiftly transitioned to remote delivery, most of the courses were designed to be delivered in a face-to-face format. Courses continued as if they were face-to-face (e.g., assigned class hours) but with online delivery; for which some students did not have the appropriate access to hardware/software and bandwidth to stay on track with lecture content. Many students had to abandon their dormitories and shelter in place in their parents’ homes, which might happen to be in rural areas or even overseas (occasionally with significant time zone differences). This resulted in poor class attendance, a lack of engagement and participation, and overall student (and instructor) demotivation. Some of the assignments (e.g., group presentations) also needed to be modified for online delivery, given that students were not going to be able to prepare and present together as a team. Instructors often secured their own online teaching tools such as Zoom accounts and provided extended office hours in order to facilitate adequate supports to students.

3.3 An Entrepreneurial Response

After the initial response, most institutions had opportunities to investigate and invest in virtual remote learning tools and strategies. Courses were redesigned to leverage the available digital tools based on the learnings from the previous semester. Many faculty members demonstrated the “Build - Measure - Learn” Lean Methodology learning cycle.

3.3.1 Digital Tools

A variety of digital tools were reported by the authors to facilitate virtual learning. For the Learning Management System (LMS), BRIGHTSPACE was used at MUN, UNB and UW, and Canvas was used at USask.

Video conferencing tools utilized included Zoom, MS Teams, WebEx, Discord, Google Meet and Toucan. Events were employed to provide video chat and breakout room sessions. MS Teams and Slack were used to provide text communications.

Collaboration tools such as MIRO, OneNote, and Google Docs were also employed.

More details about the digital tools employed in the courses are included in the appendix.

3.3.2 Virtual Lecture Delivery and Instructor's Role
For delivering the courses, three types of strategies were employed by the authors: 1) asynchronous, 2) synchronous delivery along with recording posted on LMS, and 3) flipped classroom with live sessions.

In the synchronous delivery model, the lectures were delivered over video conferencing tools in real-time, similar to a face-to-face environment. Chat and Poll functions were used to increase class participation. The lessons were then recorded and posted on their LMS.

In the asynchronous and flipped classroom model (UNB), the lectures were recorded using tools such as Open Broadcaster Studio (OBS Studio) and Panopto and then processed by tools such as Openshot Video Editor. Similarly, Panopto was employed for recording and editing for asynchronous delivery at USask. Based on literature, such videos typically range from 10-20 minutes to ensure the students can focus and complete each video at their convenience. Summative multiple-choice quizzes were employed prior to each synchronous lecture to ensure students viewed and understood the content presented asynchronously.

In using these teaching strategies, instructors became the facilitators of learning, monitoring the students’ progress through LMS analytics or quiz results. These tools allowed instructors to identify struggling students and intervene in a timely manner.

### 3.3.3 Experiential Learning

To facilitate experiential learning, digital collaboration tools were employed for collaborative teamwork. For example, activities were developed using the online collaborative whiteboard MIRO. The tool allowed students to collaborate as if they were using a physical whiteboard in a classroom. Breakout room functions were also used to enable teams to interact and work within their groups. Discussion boards in LMS were used to promote students’ interaction, peer learning, and intragroup connections. The instructor also allocated time and provided instructions for students to present their up-to-date progress to the rest of the class to create intragroup collaboration and competition in the design courses.

### 3.3.4 Engagement

Besides the in-class group discussions, many other strategies and tools were also employed to promote student engagement. For example, at UNB, PollEverywhere was used to ask questions throughout the lecture to a) motivate students to pay attention to lecture content, and b) spark points of conversation when reviewing answers to multi-select questions. At USask, Mentimeter was used for a similar purpose. At UW, weekly group workshop sessions included 4-5 person groups providing new recommendations and resources for components of each student’s business model canvas and user tests for design sprints as an iterative learning process and crowdsourcing peer feedback.

The connection between the instructors and the students is crucial to building engagement. The authors offered extended office hours to answer questions and provide more individualized coaching and mentorship. To reduce the need for back-and-forth emails, calendar management systems such as MS Bookings, x.ai, Navigate, and Calendly were set up to allow students to book meetings with the instruction teams. The certainty of establishing a communication path to talk to the instructional team was important to the students.

### 3.3.5 Assessment

Students submitted their work through online LMS. Some systems allow auto-grading for multiple-choice and numerical problems. This allows instructors to focus on providing feedback rather than grading such questions. Cloud-based PDF annotation services such as Drawboard Projects, Crowdmark, and GradeScope were used for restricted control of documents and collaborative feedback and marking between teaching assistants and instructors.

### 3.3.6 Prototyping (Design Only)

Within a virtual environment, prototyping is more challenging. However, students can present their work using video cameras and screen sharing. Engineers-in-residence supported the students with their development virtually by providing insights and connections to local companies for accessing additional equipment. This is crucial, especially when students are spread throughout large geographic areas nationally and/or globally. For students that developing software prototypes, cloud-based development environments such as Jupyter Networks (UNB) and Virtual Labs (USask) provide access and collaborations.

### 4. DISCUSSION

The following section reports the results of these strategies used in these courses.

#### 4.1 Outcomes of these Strategies

Overall, the strategies worked well to deliver the courses in a virtual remote environment. Many strategies significantly reduced the workload and complexity of certain aspects of teaching. For example, calendar management systems and virtual assessment tools drastically reduced coordination time and effort. These tools are likely to be used in future courses even in face-to-face environments. Meanwhile, tools such as MIRO and PollEverywhere motivated students to work collaboratively thus leading to more engagement. However,
they required more effort in learning how to use them effectively. Their future use will likely be re-evaluated.

4.2 Student Performance

It is difficult to fully assess the efficacy of these strategies in the current environment because of the lack of controlled experiments. The authors also observed that more students deliberately took course overloads or worked full-time in their country of residence while attending lectures. This unique aspect also makes the comparison with other years difficult. The instructors decided to use the course rubrics as a measurement to provide some understanding of the effectiveness of these strategies. It is reported that in the more content-centric courses, such as Engineering Economics, students’ performance measured by grade point averages remained the same despite the different delivery and assessment formats. However, it is worth noting the number of academic misconduct cases seemed to be higher during these semesters with remote learning than before. For the design courses, students seem to be more efficient with their time. It was also observed that their overall design quality tends to be about the same or lower. In the final assessment performed by the instructor, the students seemed to achieve a similar level of quality in prototyping.

5. CONCLUSION

The pandemic has forcibly provoked faculty members and practitioners to jump head first into teaching using online learning methods. The strategies presented in the sampled institutions represent first-hand experience concerning online learning delivery for engineering entrepreneurship, product design, and engineering economics courses. It motivated our institutions to provide training to support our students to complete their degrees while protecting our most vulnerable populations. Adopting digital tools may provide additional value to students and potential employers as students have developed proficiency with working in a remote environment as may be the case with future work scenarios post-pandemic. Future benefits may be realized for educators. For example, teaching remotely while at a conference or business trip is a viable future option.

Most Canadian post-secondary institutions considered online learning as very or extremely important for their future plans, yet less than 20% of institutions offered a MOOC back in 2017 [9]. We hope this experience will encourage educators and institutions to explore the benefits of online delivery within their degree programs, particularly in engineering entrepreneurship. The online format will provide greater access and flexibility to students and professionals seeking continuous career developments, especially for large provinces with very low population density such as Newfoundland & Labrador and Saskatchewan.

It is worth noting that this paper reports on the experiences of the authors and therefore has limited scope. Many innovations and strategies in the field of engineering entrepreneurship education are not discussed in this paper. For example, a continuous evaluation is a promising strategy the authors would like to explore in the future [27].

In the future, more resources should be identified to support students’ efforts in design, fabrication, and testing in a virtual environment. We currently do not have a good solution to this challenge and would love to learn more about experiences from our peers and colleagues.

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Appendix

| Digital Tool      | Features                  | Cost to Implement | Application in Course                                                                 |
|-------------------|---------------------------|-------------------|---------------------------------------------------------------------------------------|
| BRIGHTSPACE       | LMS                       | University licensed | Course material                                                                       |
| Canvas            | LMS                       | University licensed | Course material, online discussion board, meeting schedule, announcements             |
| Zoom              | Video communication       | Free & Paid       | Course delivery, breakout room discussion. Free version has 40 mins limit             |
| WebEx             | Video communication       | Free & Paid       | Course delivery, breakout room discussion. Free version has a limit of 8 participants |
| MS Teams          | Video & text communication| University licensed| Course delivery, breakout room discussion. No free version                           |
| Slack Teams       | Text communication        | Free & Paid       | Team communications, free version has limited conversation history                    |
| Discord           | Video & text communication| Free & Paid       | Video and text communication                                                           |
| Google Meet       | Video communication       | Free & Paid       | Video communication                                                                   |
| Toucan.Events     | Video communication       | Free              | Video conference, group work. Limited to 150 people in a toucan space, and 16 per group.|
| MIRO              | Collaboration Tool        | University licensed| Online collaboration whiteboard                                                        |
| OneNote           | Collaboration Tool        | Free & Paid       | Online notes taking                                                                   |
| Google Docs       | Collaboration Tool        | Free              | Online collaboration                                                                   |
| Poll Everywhere   | Interactive presentation  | Free & Paid       | Online polling. Free version has a limit of 25 participants                           |
| Mentimeter        | Interactive presentation  | Free & Paid       | Online polling. Free version has a limit of                                          |
| Crowdmark         | Marking                   | University licensed| Collaborative marking                                                                 |
| Drawboard Projects| Marking                   | University licensed| Collaborative marking                                                                 |
| GradeScope        | Marking                   | University licensed| Collaborative marking                                                                 |
| OpenShot          | Video editing             | Open Source       | Video editing                                                                        |
| Panopto           | Streaming & recoding      | University licensed| Online based, unlimited storage, LMS integration. Limited editing capability.         |
| Open Broadcaster Studio | Streaming & recoding   | Open Source       | Video recording                                                                      |