Offering an Entrepreneurship Course to All Engineering Students: Self-efficacy Gains and Learning Benefits

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***Abstract*— In order to develop an entrepreneurial mindset in future engineers, entrepreneurial training has become a key aspect of engineering education. Following this trend, a large and prestigious engineering school in Chile designed and implemented a third-year compulsory course on technology-focused entrepreneurship. To understand how course teaching and assessment methods have benefited students in terms of self-efficacy and learning gains, a cross-sectional survey study has been conducted since 2015. Over the last four academic periods, we assessed Pre-Post self-efficacy gains and learning benefits in 1,335 students. These survey results show that students perceived positive benefits from all course teaching and assessment methods. Thus, we discuss how a core engineering course can develop an entrepreneurial mindset in a diverse population of students.**

Keywords—Entrepreneurial Learning, Engineering Curriculum, Entrepreneurial Mindset, Learning Benefits.

I. INTRODUCTION

Engineering entrepreneurship is an evolving concept [1]. Although it started as a way to motivate future engineers to become entrepreneurs, it has recently shifted to the development of an entrepreneurial mindset among all engineering students [1]. So far, there is no consistent definition of what constitutes an entrepreneurial mindset across engineering schools [1]. Yet, researchers have referred to this concept as a complex skillset that includes: the ability to think creatively, to identify and solve problems, to contribute to technological innovations, and to create social and economic value [1]–[3].

In order to develop an entrepreneurial mindset in engineering students, there is a wide variety of initiatives [4], [5]. In developed regions, such as North America, different agencies have funded the design and implementation of initiatives to teach engineering students to be entrepreneurial (e.g. Kern Family Foundation and the National Science Foundation) [1], [6]. In developing regions, such as Latin America, governmental agencies have also motivated the implementation of engineering entrepreneurship education as a way of motivating engineers to become entrepreneurs [7].

Regardless of the growth of entrepreneurial training worldwide, few studies have demonstrated how engineering students benefit from these type of learning opportunities [1]. On the one hand, practice has highly influenced the engineering entrepreneurship field, without necessarily considering the theoretical rigor that is required to understand how different pedagogical approaches support the development of student outcomes [1]. On the other hand, most studies have documented business-driven minors and extracurricular activities [8], [9], typically taken by students with an intrinsic motivation in the field (who may have already developed an entrepreneurial mindset by their own). Thus, prior work has not necessarily addressed the development of an entrepreneurial mindset among a diverse population of engineering students [1]. In this context, more research is needed to understand self-efficacy gains from entrepreneurial learning opportunities, assessing the learning benefits of specific curriculum and teaching practices [1].

This paper presents part of a cross-cross-sectional survey study conducted in an entrepreneurship course imparted at the engineering school in Pontificia Universidad Católica de Chile (hereinafter UC-Engineering). This course was implemented in the context of a Chilean governmental program called New Engineering 2030 — an initiative which co-financed 6-year strategic plans of Chilean engineering schools focused on entrepreneurship, innovation, and technology transfer [10]. Unlike previous studies, this course is compulsory for all engineering students, which make the sample population under study more heterogeneous, without necessarily having a predisposition to entrepreneurship. In order to expand the current understanding of pedagogical approaches for engineering entrepreneurship education, this paper presents the results of a Pre- and a Post-Survey to assess learning benefits

and gains in entrepreneurial self-efficacy from the perspective of students who have taken this course in the last four academic semesters.

II. CORE ENGINEERING COURSE IN TECHNOLOGY-FOCUSED ENTREPRENEURSHIP AT U-ENGINEERING

In 2015, UC-Engineering started imparting a core engineering course in technology-focused entrepreneurship. This course initially followed the Berkeley Method of Entrepreneurship (BMOE) [11], and it is a mandatory for all third-year students — regardless of their engineering major of preference. In the past five years, the focus of this course has evolved from entrepreneurial intent to entrepreneurial mindset, aiming to provide all engineering students with skills that transcend in time and apply to entrepreneurship and intrapreneurship.

Currently, the course follows a constructivist approach in which third-year students develop entrepreneurial skills by working in 5-person teams during 16 weeks. These teams have to recognize a technology business opportunity and develop an innovative product or service that meet societal needs. By living an entrepreneurial experience as authentic as possible, students are expected to develop the following abilities:

- Identify an opportunity for the creation of an innovative product or service within a given context or topic,
- Develop a business model for a product or service, which should be supported by scientifically and technologically basis.
- Collaborate effectively in teams to develop an innovation project,
- Design an innovative project or service based on science and technology with scaling potential,
- Apply the evidence-based decision making to reduce the level of uncertainty associated with real-life problems,
- Effectively communicate ideas about technology-based innovations in oral and written format.

In order to the develop the abilities previously listed, the teaching methods combine the delivery of entrepreneurship content with business acceleration strategies. These methods include instructors' lectures about entrepreneurship topics, guest lectures in the form of Lightning talks led by Chilean entrepreneurs (or other key relevant actors related to the proposed topic), project working sessions, and project feedback sessions. Concerning course assessment methods, students are required to conduct project presentations and written reports assessed by external evaluators from private and public funds, besides homework and written exams. Project presentations include group presentations at four stages of product development: problem detection, solution mock-up, solution prototype, and a final presentation in which both the business model and the Minimum Value Product are presented. In every project presentation, peer assessments are also conducted to allow evaluation of their team work skills.

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In order to formulate improvement actions based on students' perspectives, a cross-sectional survey study has been implemented since the course started to collect evidence on self-efficacy gains and learning benefits. Figure 1 shows the improvement actions that have been implemented over the last four academic semesters. Within these periods, the course has incorporated mentoring sessions for all students (both technology and entrepreneurship focused), in addition to increasing the number of sessions regarding project work and feedback. Further details concerning the cross-sectional survey study, and the improvement actions that have been formulated as a result of it, are addressed in the Methods and Findings section respectively.

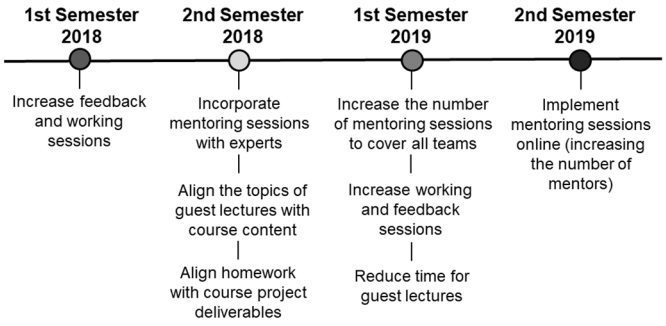

Fig. 1. Improvement actions that have been implemented over the last four academic semesters.

III. METHODS

A. Research Design and Objectives

This paper addresses the following research question: *What teaching and assessment methods are beneficial for entrepreneurial learning from the perspective of engineering students?* To meet this objective, this paper presents part of a cross-sectional survey study in the core engineering course described in section II. According to Creswell [12], this type of research design is useful to evaluate the effectiveness of educational programs from the perspective of students. In this paper, we adopted this research design to identify what teaching and assessment methods have been perceived as beneficial in a technology-focused entrepreneurship course, aiming to expand the current understanding of pedagogical approaches to develop an entrepreneurial mindset in a diverse population of engineering students.

B. Data Gathering Techniques and Participants Sample

The data gathering was conducted during the two first semesters of two academic years, 2018 and 2019. Every semester, a Pre-survey is applied during the first two weeks of the core engineering course at UC-Engineering (weeks 1 and 2), in addition to Post-survey applied once the classes are finished (weeks 17 and 18). The Pre-Survey includes the following measurements: demographics (year of birth, gender, participation in extracurricular activities, prior exposure to family entrepreneurship), and a 0 to 10 self-efficacy scale of ten items, which was adapted from Cooper and Lucas [13], and associated with the course learning outcomes (see the self-efficacy scale in the following link: http://bit.ly/ING2030_self-efficacy). The Post-Survey includes the same scale of self-

efficacy used in the Pre-Survey, in addition to a 5-point Likert scale to measure student perceptions on learning benefits from course teaching and assessment methods. Both surveys were statistically validated during the first semester of 2015, and the self-efficacy scale demonstrated high-reliability and no redundancy items.

Table I shows the number of third-year students who participated in the Pre- and Post-surveys applied in the last four academic semesters. On average, 67% of the students enrolled in the course participate in both surveys, providing self-reported changes in self-efficacy levels, besides reporting perceived learning benefits from different teaching and assessment methods at the end of the semester. These students are affiliated with different engineering majors — such as research operations, software engineering, and civil engineering, and do not necessarily have prior entrepreneurial experiences and interest.

TABLE I. PRE- AND POST-SURVEY SAMPLES

	1st semester 2018	2nd semester 2018	1st semester 2019	2nd semester 2019
Course enrollment	370	252	387	326
Pre-Post sample	267	167	266	201
Response rate[a]	72%	66%	69%	62%
Female students[a]	25%	30%	35%	34%
Students aged 20-21[a,b]	88%	76%	77%	76%

[a.] These percentages correspond to the Pre-Post sample.

[b.] Students aged 20-21 are a proxy to describe the percentage of 3-year students.

C. Data Analysis Plan

Our analysis contrasts data obtained from the last four academic periods that the core engineering course has been imparted. Concerning self-efficacy levels, we estimated significant changes of the average score of the self-efficacy scale between the Pre- and the Post-Survey. By average score, we mean the average of the summation of the responses of each student in the ten items that are part of the scale. Regarding learning benefits, we estimated the percentage of students who perceived learning benefits from different course teaching and assessment methods. These percentages were obtained by dividing the number of respondents whose scores were equal or higher than 3 by the total number of respondents, taking into account that the perceived benefits scale ranged from 1 (not beneficial) to 5 (extremely beneficial). Besides, we analyzed students' comments regarding course methods and improvement actions that were formulated at the end of every semester.

IV. FINDINGS

Figure 2 shows the percentage of students who perceived learning benefits from the teaching methods used in the core engineering course at UC-Engineering across the last four academic semesters. Although the perception of learning benefits has gradually increased every semester for most of the teaching methods, the most noticeable growth was associated with mentoring sessions and guest lectures. Over the last three academic periods, the number of mentoring sessions has been increased to cover all course teams (see Figure 1). During the second semester of 2019, these sessions were delivered online due to the Chilean social outbreak, which made attendance easier for a higher number of mentors. Regarding guest lectures, these were reduced to increase project feedback and working sessions, but these fewer sessions were delivered in a more conversational format.

Figure 3 shows the percentage of students who perceived learning benefits from course assessment methods. As teaching methods, the perception of learning benefits has gradually increased every semester for most of the assessment methods. Although project presentations are perceived as the most beneficial, there were noticeable changes associated with written exams and homework. Between the first semester and second semester of 2018, the different pieces of homework were constructively aligned to course project deliverables, so all students' efforts contributed to the progress of the course project.

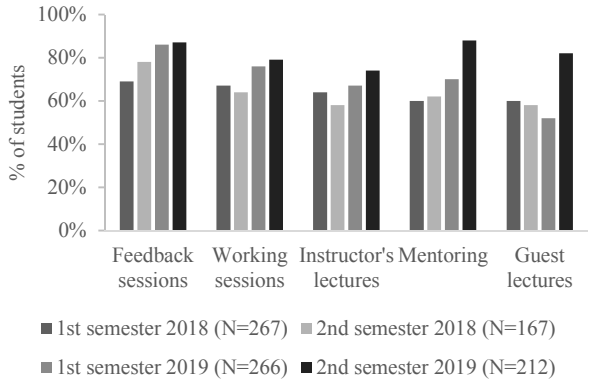

Fig. 2. Percentage of students who perceived learning benefits from different teaching methods used in the core course on entrepreneurship.

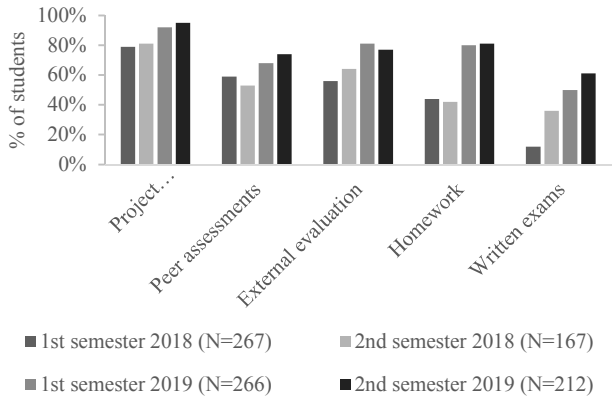

Fig. 3. Percentage of students who perceived learning benefits from different assessment methods used in core course on entrepreneurship.

Along with the perceived learning benefits from teaching and assessment methods, the overall results indicate that this course has been perceived as beneficial by most of its students. Figure 4 shows that the percentage of students who perceived

that the core engineering course is beneficial has increased from 66% to 83% across the last four academic semesters. In addition, Figure 5 shows that the overall score of students' self-efficacy has increased every semester when comparing the results of Pre- and Post-Surveys. Such an increase is statistically significant with a 95% confidence level.

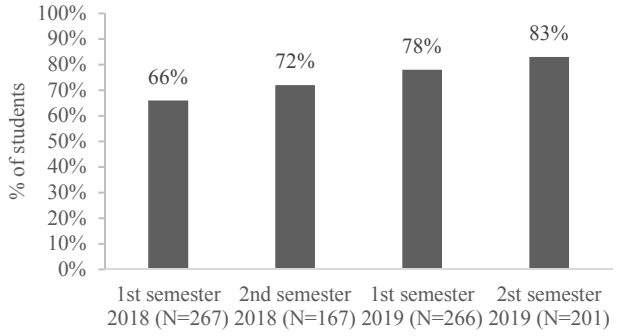

Fig. 4. Percentage of students who perceived learning benefits from the overall course experience.

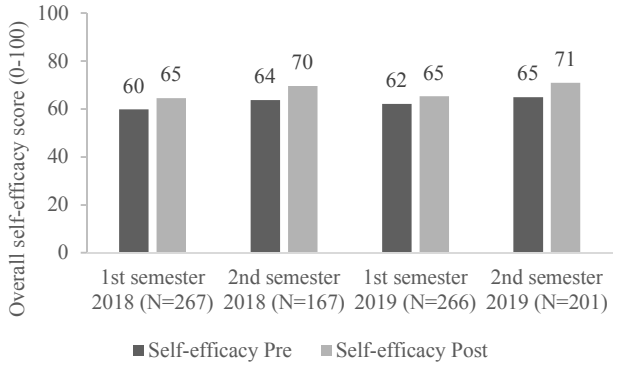

Fig. 5. Overall self-efficacy scores at the beginning (Pre) and at the end (Post) of the last four semesters (Pre-Post gains are statisficaly significant with a 95% of confidence level). See self-efficacy scale in: http://bit.ly/ING2030_self-efficacy

V. DISCUSSION AND CONCLUSIONS

This study contributes to literature on engineering entrepreneurship by illustrating how a diverse population of students benefit from a core engineering course in technology-focused entrepreneurship. According to the results of a cross-sectional survey study, students perceive benefits from all teaching methods, particularly from mentoring sessions and guest lectures delivered in a conversational format. Concerning assessment methods, not only students perceive benefits from project presentations and external evaluations, but also from homework when they are constructively aligned with the course project. In this sense, this study portrays how a compulsory course favors entrepreneurial learning in a diverse population of engineering students, regardless of whether they are interested in becoming entrepreneurs in the short term [1].

Furthermore, this study shows how collecting evidence could influence continuous improvement of engineering entrepreneurship initiatives. Since 2015, we have evaluated the effectiveness of different teaching and assessment methods using self-efficacy gains and learning benefits, being consistent with the evidence-based approach that we teach third-year students to embrace entrepreneurship. So far, most entrepreneurial initiatives have been influenced from experience, without having evidence to demonstrate the effectiveness of their curriculum and teaching practices [1], [3]. In order to increase the institutional capacity to develop an entrepreneurial mindset among engineering students, more studies have to rely on empirical evidence to understand how effective 'real-world' entrepreneurial experiences are in terms of student learning [1], [3], [14]. This organizational capacity includes the ability to use valid and reliable measurements across different academic periods.

Finally, this study demonstrates that it is possible to incorporate engineering entrepreneurship into a third-year core course. According to prior studies in engineering entrepreneurship, most of entrepreneurial learning opportunities consist of business-driven minor, certificates, and extracurricular experiences [8], with exception of few studies that have documented freshmen or senior curricular activities (such as cornerstone or capstone courses) [9]. Considering the findings of this study, we would recommend other engineering schools to explore the possibility of including entrepreneurial learning opportunities across the core engineering curriculum. Existing project-based courses could provide students the opportunity to explore problems and real-life challenges where they can apply entrepreneurial thinking and technical skills. This type of courses increases students' entrepreneurial self-efficacy to identify business opportunities or develop innovation projects, regardless of their current entrepreneurial intent. Also, help students to develop the necessary skills to manage uncertainty, a necessary competence in entrepreneurial initiatives.

Future research on engineering entrepreneurship should inform engineering education practice, aiming to create a shared understanding of what it takes to develop an entrepreneurial mindset across educational settings. More studies should propose valid and reliable measurements to evaluate the effectiveness of curriculum and teaching practices targeting entrepreneurship objectives. Considering the cross-sectional study that was presented in this paper, future work implies evaluating the improvement actions that have been recently implemented to transform the core engineering course into an online experience. Additionally, we would like to collect quantitative data in other engineering schools, in order to discuss implications for different educational systems.

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