Challenge-based learning as a practice for engineering education to develop students' entrepreneurial mindset

CHALLENGE-BASED LEARNING AS A PRACTICE FOR ENGINEERING EDUCATION TO DEVELOP STUDENTS' ENTREPRENEURIAL MINDSET

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Conference Key Areas: *Challenge Based Education, Maker projects*
Keywords: *Challenge-based learning, Student entrepreneurship, Entrepreneurial mindset, Entrepreneurial intention*

ABSTRACT

This paper aims to investigate the implications of Challenge Based Learning programs on entrepreneurial skills, mindset and intentions of university students using a quantitative approach. Using an original database, we analyzed pre and post levels of entrepreneurial skills, mindset and intention of 127 students who attended a Challenge Based Learning program. Results show a positive and significant effect of Challenge Based Learning programs on entrepreneurial mindset and skills – such as

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financial literacy, creativity and planning – of the students. Moreover, results show a positive but non-significative effect on entrepreneurial intention.

1 INTRODUCTION

Besides education and teaching, since the end of the XX Century universities have expanded their roles with the introduction of the "Third Mission", devised to contribute to cultural, social and economic development through knowledge and technology transfer activities (Etzkowitz et al., 2000). In this framework, universities today perform a broad range of entrepreneurial activities, including entrepreneurship education (EE) and support to the creation and growth of new ventures (Ricci et al. 2018). Entrepreneurship education has thus become an important activity from the perspective of professors, researchers as well as university managers (Kuratko, 2005) and a dramatic increase in the number of curricular and co-curricular offerings in entrepreneurship have been observed across the globe (European Commission 2008; Kuratko 2005; Morris et al., 2013).

Given its increasing importance, EE has more and more become the objective of academic research (Barr,2009; Duval-Couetil et al.;2021). Within the stream of the literature on EE, an increasing number of works have been devoted to the identification and definition of different teaching methodologies and learning approaches and to the analysis of their effectiveness (Dickson et al., 2008; Matlay, 2008; Oosterbeek et al., 2010). Results have shown that EE may improve entrepreneurial skills, mindset and the career ambitions of students (Sánchez, 2011; Cui et al.,2021). Moreover, experiential methodologies have proven to be particularly effective in the entrepreneurship domain (Rasmussen et al.;2005). Among such methodologies, Challenge Base Learning approaches have taken momentum.

Challenge Based Learning is a learning methodology in which students learn in a real context, dealing with challenges and real problems proposed by them or by existing firms (Chanin et al. 2018). Although the increasing diffusion of the Challenge Based Learning approach, evidence on its effectiveness is still limited (Johnson et al. 2009; Martinez and Crusat 2020; Palma-Mendoza et al. 2019;), particularly in the Entrepreneurship Education field. Moreover, previous evidence are mainly descriptive and drawn using qualitative approaches (Martinez and Crusat; 2017).

The present paper aims to empirically assess the effectiveness of Challenge Based Learning programs in improving students' entrepreneurial mindset, skills and intentions. The empirical analysis is based on an original dataset of 127 students who took part in a Challenge Based Programs proposed by a technical university in Italy.

The remaining part of the paper is structured as it follows. The theoretical background is discussed in Section 2. Section 3 describes the challenge based program in entrepreneurship under scrutiny and the methodology design. Finally, results and implications are discussed in Section 4 and Section 5.

2 Theoretical Background

The Challenge Based Learning approach is an experiential learning methodology that allows students to learn dealing with real challenges, such as founding a startup or solving real problems proposed by existing firms, supported by professors or external stakeholders. The peculiarity of this methodology is that students can apply the knowledge and competencies gained during their university career in a real context - unlike methodologies like Problem Based Learning or Project Based Learning (Membrillo-Hernández; 2019) - and develop new skills, mindset and career aspirations thanks to these experiences.

So far, the objective of the academic research on Challenge Based Learning approaches has been twofold. First, previous studies on Challenge Based Learning have focused on how to design these kinds of programs and have identified best practice in different domains (Camino et al.,2019; Membrillo-Hernández and García-García, 2020). Second, recently a still limited strand of the literature has been devoted to the understanding of the effects of Challenge Based programs on participants (Johnson et al., 2009; Palma-Mendoza et al.;2019; Putri et al. 2020)

As far as the design of Challenge Based programs is concerned, scholars and practitioners agreed that Challenge Based Learning programs should follow a framework composed of three stages: Engage; Investigate; Act (Apple Inc, 2012; Nascimento et al.,2019). The Engage stage requires participants to start with a big idea, usually the main topic of the challenge, and try to figure out possible solutions to it. At the end of the Engage stage, participants move to the Investigate stage, in which they are asked to frame the proposed solutions in tasks, draw an implementation journey and understand what is needed in order to realise the solution. In the last stage, the Act stage, participants start to implement the solution and to verify whether the solution is suitable to address the challenge or if it needs to be revised. During these stages, participants must be tutored by educators and other stakeholders, in order to guide them through the process of generation and implementation of the solution.

As for the effect of Challenge Based programs on participants, the literature has shown that Challenge Based Learning improves soft skills, entrepreneurial intention and university performance of participants (Johnson et al., 2009; Palma-Mendoza et al.;2019; Martinez and Crusat 2020). In particular, Johnson et al. (2009) investigates the effects of Challenge Based Learning approaches on a sample of 312 high school students from 6 U.S. high schools. Students involved in the study were asked to work for some months on different real and global problems – such as, for example, Sustainability of Food - in order to propose a solution to be implemented in their schools. At the end of the project, students reported that they had improved their soft skills, such as critical thinking, creativity and problem-solving. Although the study shows a positive impact of the program on students' skills, these evidence are built on self-reported information and do not allow to verify whether students' skills have

improved with respect to the pre-challenge levels. In another study, Palma-Mendoza et al. (2019) analyses the effectiveness of the I-semester program led by Tecnologico de Monterrey. The paper reveals a clear positive effect of the challenge based approach on students who participated in the program, but limited to the performance achieved in related subjects and the communication skills. Finally, an interesting evidence on the effectiveness of the Challenge Based Learning approach on the mindset and entrepreneurial intention of university students is provided by Martinez and Crusat (2020). By focusing on the Innovation Journey Challenge Based program, in which 20 teams of mechanical and electrical engineering students work on innovative solutions to real problems proposed by municipalities, startups and firms, the paper shows that the program positively affects participants' propensity to become entrepreneurs.

Building on this, Challenge Based Learning methodology seems to improve soft skills, performance and entrepreneurial intention and mindset of the participants. However, previous studies have mainly focused on generic skills and other measures of performance of participants, such as university grades, neglecting possible effects on entrepreneurial skills. Moreover, evidence on entrepreneurial intention and mindset are drawn using qualitative methodologies and do not allow to measure the extent to which students' entrepreneurial skill have improved after the program.

Building on this, this paper aims to quantitively assess whether Challenge Based Learning methodologies improve students' entrepreneurial skills, mindset, and intentions.

3 METHODOLOGY

3.1 The program

The challenge based program analysed in the paper is carried out by the CLICK university Technology Transfer Laboratory. This experimental teaching laboratory was born in September 2017 and conceived as an essential part of the university's strategy to foster innovative education and entrepreneurial culture.

After an initial settling-in period, in January 2019 CLIK organised the first Challenge_by Firms while in September 2020, the first two Challenge_by Students were added.

The Challenges, both "_by Firms" and "_by Students", are real challenges to find the most innovative idea: up to 30 Master's Degree students, divided into multidisciplinary teams with different backgrounds, look for new solutions to solve the challenges proposed. The challenges last a semester, i.e. 14 weeks, and take place in two defined teaching periods, October/January and March/June, of each academic year.

Students are divided into teams of 5-6 people and work hard to overcome the challenge by developing the most promising idea. Professors and mentors, both from a technical and business point of view, support the Teams. Also, multidisciplinary workshops are organized during the challenges to provide educational content.

The main difference between these two tracks is the following:

- Challenge_by Firms: a company or an association proposes a challenge that tackles a real problem the organization faces.
- Challenge_by Students: the Board of the Technology Transfer Laboratory identifies macro-topics (e.g. climate change, circular economy, artificial intelligence) and teams of students develop business ideas within the identified macro-topic.

This challenge based program's objective is manifold and relates to two targets: students and the local ecosystem.

The aims concerning students are the following:

- Equip students with soft skills: problem-solving, lateral thinking, team working, project management, team management;
- Promote the "Learning by doing" approach
- Promote entrepreneurial culture and behaviour;
- Promote entrepreneurship;

The objectives concerning the ecosystem are the following:

- Bridge the gap between universities and companies/ecosystem;
- Sustain local economic development;
- Support local SMEs;

3.2 Sample

This study was carried on using a sample composed by former participants of a challenge based program. The period analysed goes from January 2019 until January 2021, for 11 challenges that involved approximately 300 students. The sample includes 127 students who answered a questionnaire administered before and after participation in the Challenge Based program.

The sample includes mainly students who took part in "by Firms" challenges. In particular, Figure 1 reveals that the 89% of the sampled students participated in "by Firms" challenges, while only 11% of sampled students took part in a challenge "by Students".

Figure 2 shows the sample distribution by gender and reveals a prevalence of male students compared to female students: while males represent 66% of the sample,

females are 34%. The challenges are proposed to all the students of the university, thus belonging to three different fields of studies: engineering, architecture, and design. The distribution of students in these three fields (Fig. 3) is skewed toward the engineering area (91%), compared to the other two areas, which count only the 9% of the sample.

Finally, since the challenges are proposed in English, it may be useful to observe in Fig. 4 the distribution of students by nationality: 78% are Italian, against 22% of other nationalities.

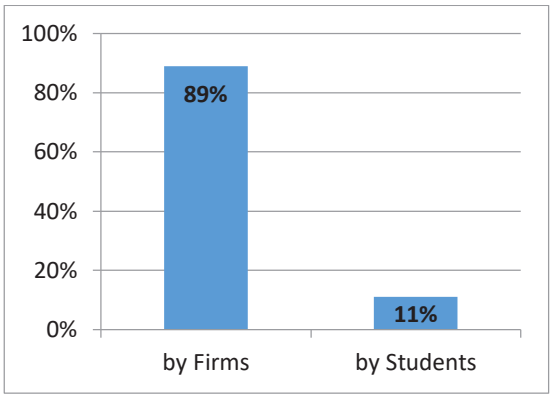

Fig. 1. % distribution of challenges by type

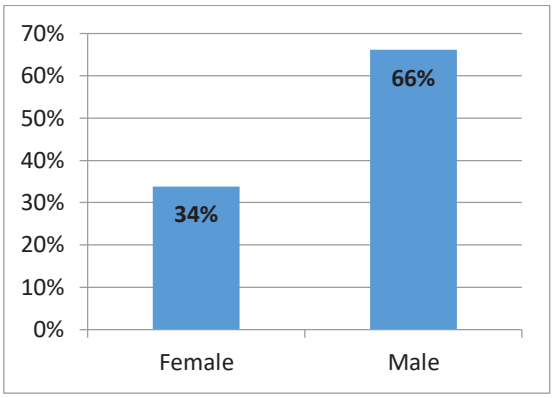

Fig. 2. % distribution of students by gender

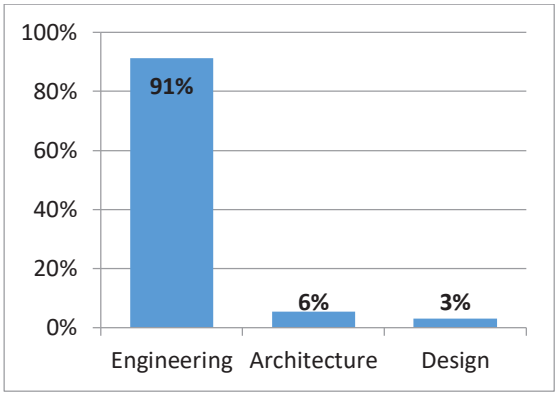

Fig. 3. % distribution of students by faculty

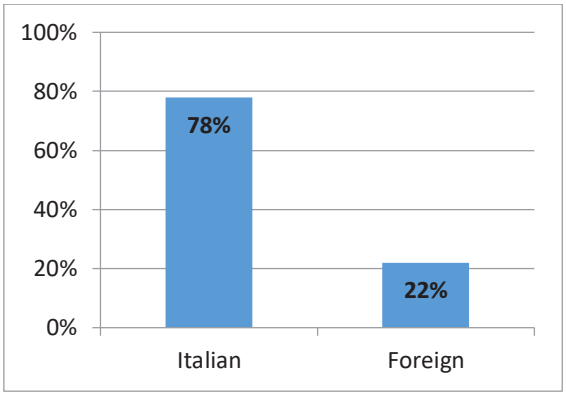

Fig. 4. % distribution of students by nationality

3.3 Description of variables and analysis

A survey was conducted on the sample presented in the previous section. Specifically, the survey aimed to assess the entrepreneurial characteristics of the students before and after participation into the program.

Entrepreneurial characteristics were measured through scales validated by Moberg et al. (2014). The variables considered were grouped into the following three domains (Table 1):

- ***Mindset***: The first domain aims to measure the entrepreneurial mindset. This variable is important to capture the respondent's sense of initiative and attitude towards challenges.
- ***Entrepreneurial skills***: The second domain variables included within this domain are *creativity*, *planning*, *financial literacy*, and *managing ambiguity*.
- ***Connectedness to labour market***: The third domain focuses on the importance for students to connect the knowledge and skills acquired to their future career. It is measured through *entrepreneurial intention*, i.e. the intention to start a business in the future.

Measurement of the variables in Table 1 was accomplished through the administration of a questionnaire to students. The questionnaire was administered once before the challenge and a second time after the challenge. This allowed for the measurement of variation in the variables due to participation in the challenge.

The choice was made to use perceptual measures of the benefits of the Challenge-based learning program. This choice could be criticised, as perceptions often differ from reality and also the use of self-reported measures invites statistical problems of common method variance (CMV) and response trends. CMV refers to false conclusions that result from “variance that is attributable to the measurement method rather than to the constructs the measures represent” (Podsakoff et al., 2003, Williams and Brown, 1994). To preempt these concerns, perceptual measures have been validated through econometric tests and factor analyses that have demonstrated satisfactory reliability.

In addition, the questions in the survey are a combination of validated constructs and constructs developed or adapted by Moberg et al. (2014). The development of these measurement tools was performed in a step-by-step process that included pre-studies and pilot testing. This increased the precision, validity, and reliability of the measurement tools.

Moberg et al. (2014) referenced the framework developed by Heinonen and Poikkijoki (2006) to develop their indicators and subsequently construct the questionnaire. This framework, which is recognised at EU level by the Directorate-General for Enterprise and Industry (DG Enterprise and Industry), illustrates the dimensions that educational initiatives should focus on to develop enterprising individuals, such as students' mindsets, attitudes, and career aspirations.

The questionnaire has a set of questions for each variable. Each question allows for the measurement of a single item of the considered variable and each question can be answered on a Likert scale from 1 to 7 (1=totally disagree, 7=totally agree). The arithmetic mean of the item values was calculated to obtain the value of a variable for a student.

Consequently, for each student, the values of the individual pre and post challenge variables were collected. For each variable in Table 1, it was possible to develop a statistic by calculating the average pre challenge value of the sample of students and comparing it with the respective average post challenge value.

Factor Analysis were conducted to verify the appropriateness of the items for the individual variables. The Factor Analysis revealed six factors that explain 80 per cent and 76 per cent of the variation of the items, respectively for the pre and post challenge surveys. Cronbach's α for the six factors, both pre and post challenge, were more than 0.68. After the Factor Analysis and processing of statistics, a t-test was conducted for each variable to test for the presence of a statistically significant impact of the challenges on students' entrepreneurial characteristics. Results are presented in Section 4.

Table 1. Variables, and their respective domains, to measure students' entrepreneurial characteristics

Domain	**Variable**
Mindset	Entrepreneurial Mindset
Entrepreneurial skills	Creativity
	Financial Literacy
	Managin Ambiguity
	Planning
Connectedness to labour market	Entrepreneurial Intention

4 RESULTS

As anticipated in the methodology chapter, statistics were initially developed to compare the average values of students' entrepreneurial variables before and after participation in the challenge (Fig. 5). In Fig. 5, it can be observed that before the challenge the average value of students' entrepreneurial mindset was 5.29, while this value grew by 0.25 to 5.54 after participation in the challenge. Similar growth can be observed for creativity and planning. Regarding financial literacy, participation in the challenge allowed for a greater increase than the previous variables. Instead for the variables managing ambiguity and entrepreneurial intention, a smaller increase in average values can be observed.

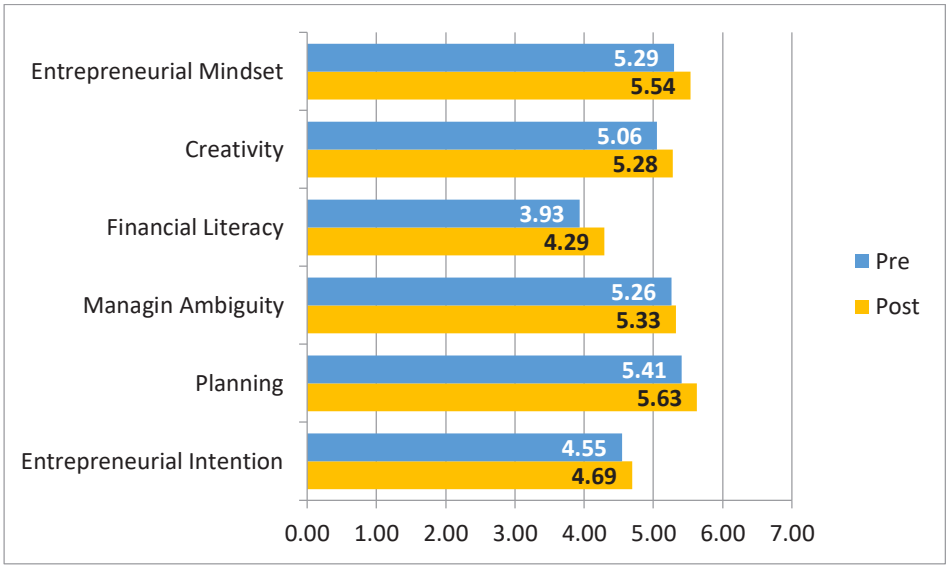

Fig. 5. Average value of entrepreneurial characteristics, pre and post challenge

After these initial statistics, a t-test was conducted (Table 2) to test the effect of the program on students' entrepreneurial characteristics. A significance level of 5% is considered.

Results show that the difference between the post and pre challenge of the entrepreneurial mindset is statistically significant and positive, so participation in the challenge increases the average value of this variable.

As for entrepreneurial skills, it is possible to note (Table 2) that the difference between the post and pre challenge is positive for all variables. However only creativity, financial literacy and planning are statistically significant. Finally, also entrepreneurial intention reveals a positive difference between the post and pre challenge, although it is not statistically significant.

In sum, results in Table 2 show that the challenge based program positively affect the entrepreneurial mindset and skills, like creativity, financial literacy and planning, of participating students.

Table 2. Output t-test

Variable	Average pre challenge	Average post challenge	Ho: diff = avg post challenge – avg pre challenge	p-value Ha: diff>0	p-value Ha: diff!=0
Entrepreneurial Mindset	5.293963	5.538058	.2440945	0.0196	0.0391
Creativity	5.055118	5.279528	.2244094	0.0366	0.0733
Financial Literacy	3.934383	4.288714	.3543307	0.0256	0.0512

Managin Ambiguity	5.257874	5.326772	.0688976	0.2976	0.5951
Planning	5.411417	5.629921	.2185039	0.0376	0.0752
Entrepreneurial Intention	4.545932	4.690289	.144357	0.2567	0.5135

5 LIMITATIONS OF THE STUDY

The study addressed student attitudes and intentions before and after the Challenge, but not actual student behavior in the periods following Challenge participation. It is echoed by the suggestion that longitudinal studies that follow subjects for years after graduation is the only way to accurately prove the intention-behavior link (Kolvereid, 1996a). In future research on entrepreneurial education, the effect of Challenge-based learning programs could be longitudinally tested, by investigating and analyzing the eventual creation of ventures.

6 CONCLUSIONS

This paper presents the results of a research project to assess the effectiveness of challenge based programs on students' entrepreneurial skills, mindset, and intentions. The paper contributes to the increasing but still limited stream of the literature on Challenge Based Learning approaches. The project has involved 127 students who answered to a questionnaire administered before and after participation into the challenge base program. Results reveal that the program positively and significantly affects the entrepreneurial mindset and skills, like creativity, financial literacy and planning, of participating students. The empirical evidence also shows an increase in students' entrepreneurial intention, although the effect is not statistically significant.

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