Entrepreneurship Education in Engineering Courses: Critical Success Factors

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Abstract: The teaching of entrepreneurship in engineering study programs is an understudied area of research.. In an ever-changing economy where continuous innovation (much of it originating from engineering) is a prerequisite for a country's competitiveness and business growth, a purely technical education for engineers appears insufficient to provide organizations with a comprehensive contribution. The growing recognition of this contribution has led higher education institutions (HEIs) offering engineering study programs, which did not previously include entrepreneurship modules in their curricula, to introduce curricular units (CU) to fill this gap and encourage their students to explore the commercial potential of their research/technologies. This study reflects on various aspects related to the introduction of CU about entrepreneurship in the curricula of engineering courses through a literature review supplemented by observations resulting from participation in processes leading to the incorporation of CU entrepreneurship in engineering courses. We identified several factors that can contribute to the success of entrepreneurship in these study programs: (i) the emphasis on innovation and entrepreneurship policies in society; (ii) the involvement of the institution and its leaders in the curricula change; (iii) the presence of teaching staff with a profile suitable for teaching entrepreneurship; (iv) students' favorable attitude towards entrepreneurship. Additionally, our reflection suggests that defining the objectives of the curricular unit should consider the specificities of engineering courses. Furthermore, the selection of content should take into account the students' need to develop the essential skills required for creating a business. The study concludes that adopting a more practical approach oriented towards creating new enterprises, involving entrepreneurs in teaching, and providing facilitating conditions for the development of business ideas within the institution are essential. By identifying various factors that can contribute to the success of introducing entrepreneurship subjects in engineering courses, the paper offers valuable insights for educational institutions to understand and address potential obstacles during the implementation process. The paper also contributes to the debate and sharing of best practices among educators and researchers.

Keywords: Entrepreneurship; Entrepreneurship Education; Engineering Education

1. Introduction

In an ever-changing economy where continuous innovation (much of it originating from engineering) is a prerequisite for a country's competitiveness and business growth, a purely technical education for engineers appears insufficient to provide organizations with a comprehensive contribution. Sheppard et al (2008) argue that engineers nowadays require more than just "technical expertise"; they need additional skills that make them capable of leading teams and understanding the context of market and business pressures. Engineers who receive some entrepreneurship education are better prepared to grasp fundamental business aspects within organizations, integrate interdisciplinary teams, excel in communication, take on managerial roles, develop critical thinking, and motivate their colleagues to embrace an innovative mindset (National Academy of Engineering, 2004). Some literature has confirmed the effectiveness of entrepreneurship education on the entrepreneurial intention of science and engineering students (Maresch et al 2016).

While entrepreneurship education is important for performing roles within established companies, it holds even greater relevance for engineering students who aspire to start their own ventures upon graduation. This trend has been growing over the past two decades due to a combination of factors. These factors include the increasing difficulty for young graduates to find employment, the opportunities presented by the internet economy (where setting up a business often requires just a website), shifts in mentalities, simplified bureaucratic processes for business creation, and financial support available for self-employment or launching new government programs to stimulate entrepreneurship.

Teaching entrepreneurship in engineering courses equips students with essential knowledge and tools while fostering attitudes necessary to (i) identify and create new business opportunities; (ii) practically exploit those opportunities; and (iii) compete with others for a share of the market.

Interest in entrepreneurship within engineering education has been amplified both by policymakers recognizing entrepreneurship's role in driving innovation, reviving economic growth, and reducing unemployment, and by

media portraying various tech entrepreneurs as successful leaders of global companies. Higher education institutions offering engineering courses, which previously did not include entrepreneurship in their curricula, have started introducing entrepreneurship curricular units and encouraging their graduates to explore the potential of their research and technologies.

Based on a literature review complemented by observations from participating in the introduction of entrepreneurship in engineering courses at polytechnic higher education institutions in Portugal (two master's and one bachelor's degree programs), this study reflects on several critical aspects of the process of incorporating entrepreneurship into engineering education. Our paper resulted from a fruitful interaction between theory and practice and is organized around three key questions: (1) obstacles and facilitators in introducing entrepreneurship education in engineering courses; (2) pedagogical objectives, content, and teaching models for entrepreneurship in engineering courses; (3) institutional support in developing business ideas. Lastly, we present the conclusions and recommendations derived from our reflections.

2. Critical Aspects of Introducing Entrepreneurship in Engineering Courses

The literature identifies several aspects, both external and internal to higher education institutions that can critically contribute to the success of introducing entrepreneurship content in engineering courses. Below, we identify the most relevant ones.

2.1 National Environment

The dissemination of innovation and entrepreneurship values and the appreciation of research and development policies in society provide a stimulating environment for Higher Education Institutions offering engineering courses to incorporate entrepreneurship into their strategy. The presence of multiple and diversified organizations within a country that can support entrepreneurial initiatives and the availability of funding for innovative activities are also factors that foster the integration of entrepreneurship into engineering curricula (CE, 2008).

The education system of a country can also play a crucial role. HEIs find greater receptivity to integrating entrepreneurship-related content into non-business study plans when there are already high schools subjects covering basic entrepreneurship concepts. As a result, students have already developed a set of values, attitudes, and behaviors, including the encouragement and appreciation of initiative and creativity, communication and interaction skills, openness to change and new ideas, and the ability to deal with uncertainty and risk management (Godinho and Simões, 2015).

2.2 Involvement of the Higher Education Institution

Success in integrating entrepreneurship curricular units into engineering courses requires some change in traditional engineering teaching methods and a certain level of willingness from the Higher Education Institution to support, or at the very least not reject, the changes in the curriculum. The presence of a bureaucratic culture or conflicting positions regarding the need to introduce entrepreneurship education in engineering courses can lead to inertia and delay in curricular changes. The process can also become deadlocked when there is a lack of awareness or motivation at the level of the HEI and its decision-makers regarding the benefits of incorporating entrepreneurship into the study cycle. The successful implementation of the curriculum adjustment may face delays if HEI decision-makers lack motivation and fail to provide the necessary human and financial resources promptly. To ensure success, the HEI and its decision-makers must be aware of the need for change, actively participate in the process, allocate the required resources, and support those responsible for its implementation. This transition becomes smoother when there is an entrepreneurial culture within the institution, acknowledging entrepreneurial initiatives taken by students and teaching staff, and when entrepreneurship education is deemed a strategic objective.

Including entrepreneurship content in engineering courses can result from a decision made by the coordinator of the study cycle or, as often happens in Portugal, it may stem from an external recommendation from the national authority responsible for evaluation and accreditation. In processes we have participated, some obstacles arose when the HEI was divided into schools and their respective departments worked with significant independence. The lack of cooperation between schools or departments can be a compromising obstacle for the entire process. When the change is driven by an external recommendation, the team responsible for modifying the curricula may not all be equally committed since the introduction of the new curricular unit often

requires the suppression/merging of core curricular units within the program. Regarding the size of the team responsible for this process, Byers et al. (2013) found that small teams led successful experiences in engineering courses.

2.3 Involvement and Profile of Teaching Staff

Any changes to the syllabus structure need to take into account the composition of the HEI's teaching staff. Particularly crucial for the successful introduction of entrepreneurship into the study plan is having faculty members with the appropriate profile for teaching entrepreneurship. It is known that the majority of HEIs, especially those exclusively focused on engineering education, do not have entrepreneurship experts on their faculty, and for economic reasons, they may try to address the situation internally with faculty who are not specialists in the field. If the teaching staff at the HEI predominantly holds a conservative view that engineering students should only acquire technical knowledge, the collaboration of such teaching staff can potentially doom the curricular change to failure from the outset. The process is more facilitated when the HEI houses both engineering and business courses, as there can be a sharing of faculty members.

One of the prerequisites for achieving a higher level of entrepreneurship education in engineering courses is to ensure that the faculty members teaching the entrepreneurship course are familiar with the business world. Entrepreneurship courses taught by faculty who have never had any contact with the realities of the business world are unlikely to spark students' interest.

2.4 Students' Attitudes Towards Entrepreneurship

Another aspect that can facilitate or hinder the curricular restructuring to incorporate entrepreneurship content is the attitude of engineering students towards entrepreneurship (Barba-Sánchez and Atienza-Sahuquillo, 2018). Perceived attitudes and values associated with entrepreneurship among engineering students have been studied in Portugal. Vieira and Rodrigues (2014) concluded that engineering students are aware that entrepreneurship content can broaden their career perspectives and choices, while also recognizing that entrepreneurs have a positive image in society. However, they have doubts about what is best for them: becoming an entrepreneur or being an employee in a large company. Perceived abilities and competencies of the students suggest high adaptability, confidence, technical expertise, and result-oriented orientation. Octício (2012) studied entrepreneurial intentions among students at a prestigious engineering university in Portugal and found that about 3/4 of students did not intend to start a company, with greater receptivity among chemical engineering and biological engineering students. This author also observed a general trend of increasing interest in entrepreneurship among first and final-year students.

3. Pedagogical Objectives, Contents, and Teaching Models

The increasing integration of entrepreneurship curricular units in higher education has resulted in a diversity of pedagogical objectives, contents, and approaches across various courses. Hills (1988) proposes two main objectives for entrepreneurship education: (i) raising students' awareness that entrepreneurship can be a career option, and (ii) enhancing their understanding of the process of starting a new business. Garavan and O'Cinneide (1994) add that this education should challenge the aversion to risk associated with analytical techniques and foster a positive attitude towards change. Wadhwa and Freeman (2010), while agreeing with the mentioned generic objectives, believe that (i) the core education obtained in engineering courses generates opportunities for starting businesses in more innovative industries, and (ii) engineering students are even more inclined to start a business than students from other scientific fields. Therefore, for these students, entrepreneurship education should be an opportunity to develop the skills necessary to create a business related to their technical expertise. This specificity should be considered when defining the objectives of an entrepreneurship curricular unit in an engineering course.

Mäkimurto-Koivumaa and Belt (2016) recommend that entrepreneurship education elements should be distributed throughout different years of the engineering course. A study conducted in the USA highlights a lack of clarity regarding how course contents are defined (Besterfield-Sacre et al, 2016). In the Portuguese context, Redford (2006) found that the majority of entrepreneurship courses include topics such as "identifying and evaluating business opportunities," "market analysis," "business plan," "interpersonal relations," "entrepreneurial attitudes" "legal aspects of company creation," "marketing," "intellectual property" "support for company creation," and "financing." There does not seem to be a significant difference in content regardless of whether the courses are integrated into engineering programs or not. Some HEIs, in order to optimize

resources, offer the same entrepreneurship curricular unit to all study programs. This approach might not be the most appropriate, as contents designed for engineering students should take into account that, despite their solid technical background, they might have limited knowledge of business-related topics and may need basic understanding of economics, management, and marketing. Adopting a more practical approach, with examples from their specific engineering field, focusing on topics like "intellectual property," "commercialization process," "marketing," and "venture capital," seems more relevant in these study cycles.

Various approaches to deliver the knowledge and experiences lead engineering students to become innovative and entrepreneurial. Fernandes et al. (2017) delineated various fundamental aspects concerning the promotion and perception of entrepreneurship education among engineering students. Notably, their work underscores the significance of teamwork, active participation in projects, and a profound comprehension of the market. These elements are emphasized as pivotal for fostering and advancing entrepreneurial skills. Neck and Greene (2011) consider an approach based on methods that value iteration and creativity to be more effective. In engineering courses, a more practical and assertive approach focused on establishing new businesses (entrepreneurship education) might be more effective than alternative approaches identified by Hannon (2005): a more traditional and theoretical perspective on the subject (education in entrepreneurship) and a second one, where entrepreneurial practice is applied to everyday life (education through entrepreneurship). Besterfield-Sacre et al. (2016) consider that entrepreneurship courses should focus on teaching entrepreneurship skills and on developing entrepreneurial values and attitudes among students. Duval-Couetil et al. (2016), examining the role of entrepreneurship program models and experiential activities on engineering student outcomes, report those students' higher perceptions of entrepreneurial knowledge were associated with involvement in experiential learning activities. Berglund and Wennberg (2006) analyze creativity by comparing engineering and business students involved in an entrepreneurship program. Both groups demonstrate a high creative potential. While business students use a more speculative approach and have a greater focus on the market, engineering students, apply creative behaviors in a very pragmatic way. Duval-Couetil et al. (2021) recommend replacing traditional lecture-based courses by teaching/learning models based on experiential pedagogical approaches centered on real-life project development or problem-solving situations. Fayolle et al (2021) after reviewing the literature in this domain, consider that there is an emphasis on the importance of learning by doing, teamwork, interdisciplinary and involvement in projects.

Furthermore, it is important to enrich entrepreneurship education in engineering by involving local successful entrepreneurs or alumni, inviting them to share their experiences with students. In the cases we have participated, the HEI was located far from regions with a stronger entrepreneurial ecosystem, which could limit the possibility of such collaboration. Another potential limitation could be related to biases some prominent entrepreneurs may hold towards less prestigious HEIs or certain education subsystems, leading them to underestimate the contribution of these institutions to economic development. The emergence of distance learning resources can be particularly useful for teleconferences and delivering digital content inside and outside the classroom.

4. Support Students in Business Idea Development

Qureshi and Mian (2021) focused on the question of the incentives that universities use to motivate researchers to commercialize their discoveries in products, services and processes. In the authors' opinion, the main obstacle to such activities is the gap between education in scientific areas and the knowledge and tools needed to prepare students for entrepreneurship.Entrepreneurship curricular units in engineering study programs increase the likelihood of some students working on the feasibility study and development of innovative products, services, or processes. It is essential, therefore, for the institution to welcome and encourage these students to continue evaluating the potential of their research/technologies even after completing the entrepreneurship curricular units. To achieve this, some HEIs in Portugal have created internal regulations on intellectual property, entrepreneurship support offices, or knowledge transfer centers. HEIs can also become partners in technology-based entrepreneurship programs or idea competitions.

An example of collaboration among higher education institutions occurs in Portugal, where the 15 Portuguese polytechnic institutes jointly created "Poliempreende," a competition for entrepreneurial ideas and projects aimed at fostering and stimulating entrepreneurship and providing professional opportunities through self-employment. In “Poliempreende”, students have the opportunity to submit their business ideas for evaluation by a jury. In the initial stage, there is a regional competition developed through actions promoted by each polytechnic institute to select the best project. The winning projects from each polytechnic are then submitted for evaluation by a national jury, which selects the top three projects.

If the idea proves successful and a company is established, students should be able to continue with the support of the HEI's incubator, where the company is housed, takes its initial steps, and receives assistance in integrating into innovation and distribution networks, obtaining venture capital, and exploring strategic partnerships with other technology companies.

5. Conclusions and Recommendations

This study reflects on various aspects related to the integration of entrepreneurship curricular units into engineering study programs. Several critical factors have been identified that can contribute to the success of this process in higher education institutions. An environment where the values of entrepreneurship are widespread and policies on research, development, innovation, and entrepreneurship are valued serves as a significant stimulus for HEIs to incorporate entrepreneurship into their teaching strategies. For the process to be successful, it is also crucial that the institution and its decision-makers are aware of the need for change, actively engage in it, allocate the necessary resources, and encourage those responsible for its implementation. Another prerequisite for achieving a high level of entrepreneurship education is ensuring that faculty members teaching the entrepreneurship curricular units have an appropriate profile and are familiar with the business world. Equally important is a favorable attitude towards entrepreneurship among engineering students.

Regarding pedagogical objectives, content, and teaching models for entrepreneurship in engineering courses, our reflection points towards considering the specificities of engineering programs when defining course objectives and selecting content that enables students to develop the necessary skills to create a business. Teaching approaches that are more practical, based on student participation, and enriched with contributions from alumni and entrepreneurs should be favored. It is also relevant for HEIs to have internal regulations on intellectual property, business idea competitions, entrepreneurship support offices, knowledge transfer centers, and incubators where students can continue evaluating (and realizing) their business ideas and ventures.

Lastly, as a recommendation, it is important for HEIs to evaluate the impact of introducing entrepreneurship into engineering courses and promote debates and sharing of best practices among faculty members and researchers interested in entrepreneurship education, aiming to enhance teaching staff skills and improve the quality and impact of entrepreneurship education.

We would like to suggest some avenues for further investigation, namely an in-depth analysis of the critical success factors identified by investigating whether in other courses or areas, for example AI education, these factors would remain the same or would be substantially different.

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