

Entrepreneurial Education Opportunities for Engineering Students within the Engineering Curriculum at Australian Universities

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CONTEXT

In recent years, many engineering academics and professional associations have been emphasising the importance of entrepreneurial skills for engineers in fostering innovations within the engineering industry. Given the importance of entrepreneurship for engineers, educational institutions around the world have begun incorporating different entrepreneurial educational activities into engineering curricula. At the same time, researchers and educational institutions have different perspectives on how to prepare entrepreneurial engineers, what topics should be taught and what competencies they should possess.

PURPOSE OR GOAL

In this paper, entrepreneurial opportunities for engineering students within will be reviewed. The goal of this study is to review the current state of entrepreneurial education within engineering courses and highlight the development tendencies.

APPROACH OR METHODOLOGY/METHODS

To review the current state of entrepreneurial education within the engineering curriculum, the authors analysed Australian universities' materials related to the engineering curriculum, such as course overviews or subject descriptions that are publicly available. The systematic review of acquired materials was conducted to map out the entrepreneurial opportunities available to engineering students.

ACTUAL OR ANTICIPATED OUTCOMES

The findings of this study demonstrate and map out the variability and diversity of entrepreneurial education initiatives offered by Australian universities to engineering students.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The results of this study provide critical grounding for educators, higher education stakeholders, and researchers to enhance entrepreneurial initiatives in engineering courses. At the same time, this study may be used to understand the current state of an entrepreneurial education ecosystem within Australian higher education engineering courses.

KEYWORDS

Engineering education, entrepreneurial competencies, entrepreneurial engineering.

Introduction

Engineering professionals with well-developed entrepreneurial capabilities are becoming a drive force for startups and business development. That is why, in recent years, more and more professional associations and academics have emphasised the importance of entrepreneurial skills and mindset for engineering professionals. For example, the Engineering Future 2035 report prepared by the Australian Council of Engineering Deans (ACED) states that entrepreneurship and innovation capabilities will be required for future engineers for 'creating new technologies' (Crosthwaite, 2019), while Huang-Saad et al. (2020, p.4). state that modern engineering should be 'entrepreneurial in their thinking and actions to effectively contribute to the advancement of technological innovations'.

Considering the benefits of entrepreneurial skills for engineers, various educational organisations around the world are trying to integrate these competencies into engineering curricula. Previously, entrepreneurship was mainly taught within business schools, but over the past decades, there has been a significant growth of entrepreneurial concepts outside of business schools (Morris et al., 2013; Huang-Saad et al., 2020). Entrepreneurship can be incorporated into engineering curricula in different ways, such as by integrating into engineering programs innovation and entrepreneurship projects (e.g. Soares et al., 2013) or by offering engineering students entrepreneurial-focused subjects or units (e.g. João & Silva, 2018). However, despite some progress in developing entrepreneurial pedagogy and theory over the past few decades, entrepreneurial scholars highlight the lack of standards and consensus regarding content and pedagogical approach in the field of STEM education (sciences, technology, engineering and mathematics) (Turner & Gianiodis, 2018). This lack of consensus has created a situation where educational organisations are introducing entrepreneurship into the engineering curriculum, each in their own unique manner.

In this paper, the entrepreneurial opportunities within the Australian engineering curriculum will be mapped out. Firstly, the pedagogies used within entrepreneurial educational activities, examples of entrepreneurial intervention within existing engineering programs, and their benefits from scholarly materials will be discussed. Then, the methodology that was used to explore entrepreneurial opportunities within engineering programs in Australian universities will be explained. Finally, the identified results and common patterns will be presented.

Literature review

Entrepreneurship can be designed and introduced to engineering students in different ways. According to Standish-Kuon and Rice (2002), there are several main models for introducing entrepreneurship to science and engineering. Firstly, entrepreneurial engineering programs can be organised by business schools in close collaboration with engineering and science schools. Secondly, it can be organised by engineering school programs. In this case, the programs designed by engineering schools co-existed with programs offered by a business school. Thirdly, entrepreneurial programs for engineers can be organised using the multi-school approach when a technological entrepreneurship curriculum is developed by different schools.

In terms of pedagogical approaches, one of the common approaches that is used to teach engineering students entrepreneurship is project-based activities. There are different types of projects that can be used to teach engineering student entrepreneurship. Hagvall Svensson et al. (2020) identified the following pedagogies used to deliver entrepreneurial project-based activities such as through student-framed and user-oriented projects (e.g. Design or Business idea projects), through client-framed and student-driven projects (e.g. Product modelling project or through co-creation platform projects (e.g. Car-building or research projects). At the same time, after reviewing the paper of different authors Hagvall Svensson et al. (2020) also outline the importance of experiential learning approaches when entrepreneurial experiences are enabled in an engineering curriculum.

Several competency models have been widely used when discussing the competencies engineering students should acquire studying entrepreneurship. Firstly, the Kern Engineering Entrepreneurial Network (KEEN) (KEEN, n.d.) proposed the 3Cs framework that can be used to teach entrepreneurship to engineering students. This framework emphasises the necessity to foster curiosity, creations among engineering students and encourage them making connections. The other common framework used to incorporate entrepreneurial mindset into engineering courses is the EntreComp framework developed by the European Commission (Bacigalupo et al., 2016). This competency framework covers three competence areas that are tightly intertwined such as 'Ideas and opportunities', 'Resources' or 'Into Action'. These areas include 15 different competencies such as creativity, vision, planning and management, working with others, self-awareness, financial and economic literacy etc.

Entrepreneurship education can bring various benefits to engineering students. For example, Grecu and Denes (2017, p.5) conclude that 'Entrepreneurial education equips students with abilities that increase their employment potential and include: the abilities to solve problems, to develop social interaction, abilities to find information and to handle it for decision making, planning, communication and presentation skills, etc'. Integrating entrepreneurial and innovation concepts may also positively affect students' retention and performance. In their longitudinal study, Ohland et al. (2004) revealed that engineering students who attended the Engineering Entrepreneurs Program at North Carolina State University demonstrated higher retention rates and GPA results than non-participants.

However, despite the benefits of entrepreneurship for engineering students, as well as the variability of existing approaches to teaching entrepreneurship and the diversity of the types of programs, there is currently a lack of consensus or clear standards on what entrepreneurship programs should present in terms of content and regarding the method of delivery of entrepreneurial competencies (Huang-Saad et al., 2018) In this regard, universities and other educational institutions are currently choosing their own approaches to teaching entrepreneurship to engineers. This situation, with a lack of consistency among entrepreneurial engineering courses and programs, creates some difficulties related to assessment methods as well as the generalisation of best practices (Duval-Couetil et al., 2010).

In this study, the entrepreneurial opportunities for engineering students within the curriculum of Australian universities will be investigated to understand the current situation with the delivery of entrepreneurship for engineering students. This study should help understand the popular approaches and methods used to deliver entrepreneurial competencies. It is expected that this study will provide a starting point for understanding the holistic ecosystem of entrepreneurship education for engineering students in Australia and will help academics and researchers understand all the elements that constitute this ecosystem.

Methodology

The main goal of this review study is to understand how entrepreneurship is manifested within the engineering curriculum of Australian universities, this study was guided by the following research question:

How are entrepreneurial opportunities manifested within the engineering curricula of Australian universities for engineering students?

To answer the formulated research question, the authors analysed Australian universities' materials related to the engineering curriculum, such as course overviews or subject descriptions. When selecting the engineering curriculum materials for the analysis, authors specifically focused on selecting those with the presence of the words starting with "entrepreneur" within the materials according to the sampling procedure described further.

According to Tranfield et al. (2003), the systematic review of materials should be based on a specific research question, followed by the "identification of keywords and search terms, which are built from the scoping study, the literature and discussions within the review team" (p. 215). At

the same time, the authors add that only materials that meet all the criteria should be added to the review.

The first step of this study was to collect the list of Australian universities. The authors of this study recognise the fact that engineering programs with an entrepreneurial component may also be offered by other educational institutions. However, as stated above, the purpose of this study is not to list all existing ways of teaching entrepreneurship to engineering students within the Australian engineering curriculum, but only to formulate a general understanding about the entrepreneurial education ecosystem for engineering students for the future research studies focused on investigating entrepreneurial opportunities for engineering students. Therefore, at this stage, the authors of the study decided to focus only on Australian universities. The list of all Australian universities was obtained from the Study Australia website (2024). The website was accessed on 20/06/2024.

The second step of this study was to determine the search terms to identify the materials such as course overviews or subjects/units' descriptions related to engineering programs that involve any entrepreneurial components. Authors used the Google search with the following query:

engineer AND entrepreneur* AND <university name>*

After a search query demonstrated a specific source on an official university website, the authors examined it for the presence of any words starting with 'entrepreneur'. When the link was from a different website, the author's searched for the same course available on the official university website to confirm it still exists. Prince et al. (2021) attempt to conceptualise entrepreneurship as encompassing all acts of entrepreneurial activity. The authors outline the following groups of definitions associated with entrepreneurship: entrepreneurship as business or organisation creation, entrepreneurship as an act within uncertainty, entrepreneurship as opportunity recognition and evaluation, as well as value creation, and entrepreneurship as a concept related to innovation. This study focuses on the opportunities associated with business creation processes. That is why some entrepreneurship-related concepts, such as innovation, design, etc. were not included in the study. For example, if the authors came across a subject called Innovation in Engineering and the description of the subject did not contain words starting with 'entrepreneur' or 'business creation', this material was not included in the study. The search results revealed the descriptions of degree programs (bachelor, double degrees, masters), subjects/units, as well as programs majors and minors.

Results

The results of this study demonstrated that 20 out of 42 universities in Australia have different types of entrepreneurial opportunities with engineering curricula. It is important to mention that some universities listed on the website used in this study do not have engineering programs in their course pool. In this regard, this indicator cannot be used to draw conclusions about the state of entrepreneurship education in engineering in Australia, but it only demonstrates the number of universities that attempt to incorporate the concept of entrepreneurship into the engineering curriculum.

Entrepreneurial opportunities within the engineering curriculum are delivered via four categories of educational activities such as via double degrees, postgraduate engineering programs, entrepreneurial minors and entrepreneurial engineering units or subjects. The results of the study are presented in Figure 1. This Figure demonstrates the number of universities that provide entrepreneurial opportunities within a certain type of an educational activity. It is worth noting that some universities may be represented in the Figure more than once as these universities provide entrepreneurial opportunities that fit several categories. For example, engineering students in one university may be offered an entrepreneurial engineering subject and an entrepreneurial minor.

The number of universities that offer entrepreneurial opportunities within the engineering curriculum

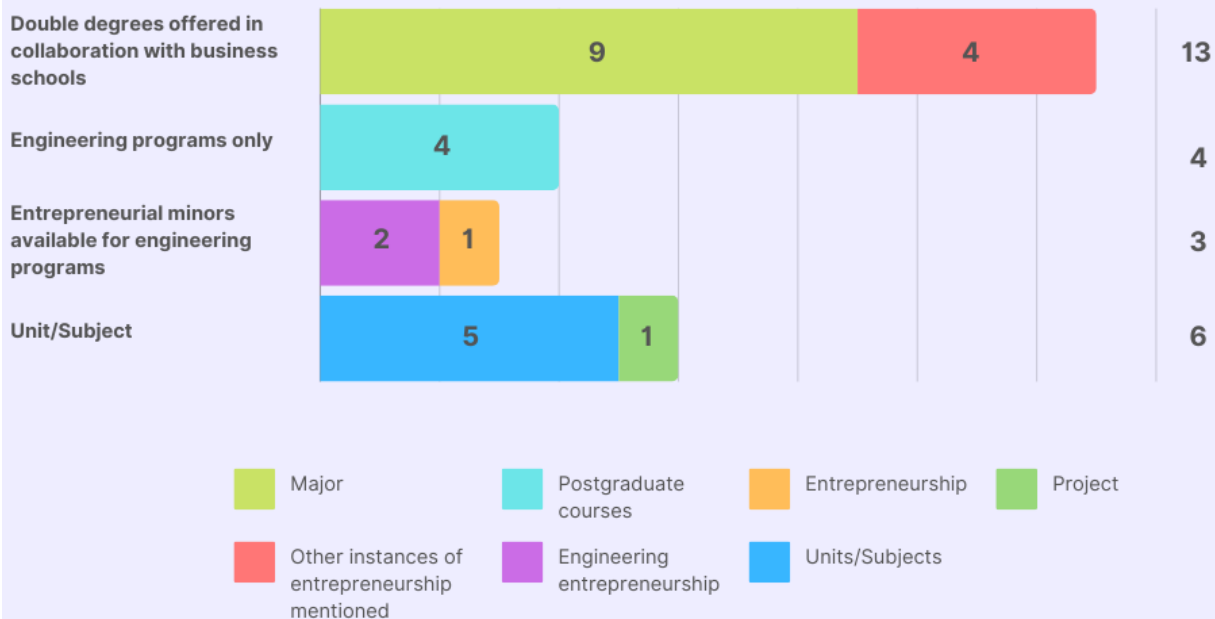


Figure 1: Entrepreneurial education opportunities for engineering students within the engineering curriculum at Australian universities

Firstly, the results demonstrate that engineering students in 13 universities can study entrepreneurship within double degrees. All the identified opportunities offer undergraduate engineering programs in collaboration with business schools. Nine out of thirteen universities offer entrepreneurial majors. All these nine majors are offered by the business schools. The materials of the remaining four universities also mention entrepreneurship in the course descriptions. The materials from one university say that as part of a double degree program, students can develop entrepreneurial skills. The materials from the second of the four universities promise students the opportunity to participate in entrepreneurial initiatives. Materials from two other universities mention that after graduation, students can become entrepreneurs.

Secondly, entrepreneurship opportunities can be offered within engineering programs. After analysing the course materials, it was identified that four universities offer postgraduate engineering programs that mention entrepreneurial opportunities. Two postgraduate programs focus on engineering management discipline. The other two are masters of engineering programs. The identified materials state that engineering students within these four programs have a chance to develop entrepreneurial skills or competencies and take part in entrepreneurial activities.

Three universities in Australia offer entrepreneurial minors to engineering students. While one university offers a minor called "entrepreneurship," the other two universities offer minors called "engineering entrepreneurship" and "engineering innovation and entrepreneurship" that are

designed to help engineering students develop their entrepreneurial skills considering the engineering context.

Finally, it is identified that six universities offer engineering students different entrepreneurial subjects/units. As stated above, this study presents subjects that contain both entrepreneurship and engineering in their title or description. The results of this study demonstrate that engineers at the two universities have the opportunity to study the subject/unit called "Engineering entrepreneurship". Three universities offer the subjects/units called "Engineering Leadership/Innovation and Entrepreneurship", "Entrepreneurial Engineering", and "Entrepreneurship for Engineers", while students at one university can take the "Engineering Entrepreneurship" project.

Discussion

The results of this study demonstrate that, despite the information presented in the literature review indicating a growth of entrepreneurship outside of business schools, Australian universities' business schools still offer many opportunities for entrepreneurship studies for engineering students. The results indicate that within the Australian entrepreneurship education ecosystem, there are at least 13 programs developed and delivered in association with business schools. This may be due to the longer history of teaching entrepreneurship in business schools and, consequently, their greater expertise in developing and teaching entrepreneurship programs. The first entrepreneurship course globally was delivered at Harvard Business School in 1947, while in Australia, the first entrepreneurship course was designed in 1989 and delivered at Swinburne University of Technology (Nabi et al., 2017; Maritz et al., 2019). Since then, business schools have developed a large expertise in teaching entrepreneurship or entrepreneurial concepts. However, the development of entrepreneurship programs outside of business schools started later. Huang-Saad and Carberry (2020) note that the growth of attention to teaching entrepreneurship outside of business schools has occurred only in the last twenty years. This may mean that due to greater expertise and tradition of teaching entrepreneurship, some universities that aim to prepare entrepreneurial engineers still consider using the expertise and help of business schools when delivering entrepreneurial activities.

The study findings also indicate that some universities provide students with the opportunity to pursue entrepreneurial pathways as part of their engineering courses. For example, the results of this study demonstrate that two universities offer entrepreneurial engineering minors within engineering programs, and one offers entrepreneurship minors. This may be due to the fact that entrepreneurship involves a wide range of processes and experiences, such as opportunity evaluation and planning. In this regard, it is important to provide diverse learning experiences to prepare engineering students for entrepreneurship. After reviewing materials of different researchers and academics on the topic of entrepreneurial education, Mäkimurto-Koivumaa and Belt (2016, p. 516) conclude that 'students should have varying learning experiences in a versatile manner during their study paths' to become entrepreneurs. In this regard, academics and instructional designers integrating entrepreneurial education into engineering courses may focus on entrepreneurial minors consisting of multiple units rather than limiting to a single subject.

Limitations/Future research

As mentioned above, the main limitation of this study is that the search for materials was conducted using the query: engineer* AND entrepreneur* AND <university name>. The application of this query did not allow researchers to involve innovation, design, and creativity-related materials in the study scope, which might also be part of the entrepreneurial education ecosystem. To form a more holistic understanding of entrepreneurial education opportunities within the engineering curriculum in Australia, future researchers may also analyse the materials that include these concepts and decide whether these initiatives can be considered a part of entrepreneurial education opportunities for engineering students.

Another limitation of this study is that the list of opportunities included some programs, the descriptions of which indicate that the course contains entrepreneurial activities, but it is not

possible to verify whether the given program actually consists of any activities related to entrepreneurship or not. Future research may be focused on more detailed material analysis, such as all the program subject outlines, to investigate the entrepreneurial indicators within program activities.

Future research studies can also explore the entrepreneurial topics covered within the engineering programs or subjects/units to gain a more detailed understanding of the existing entrepreneurial opportunities for engineering students. Additionally, future research can explore not only the curriculum but also extra-curricular opportunities to map out all the existing entrepreneurial opportunities for engineering students in Australian universities. Finally, the opportunities listed in this study can be further investigated to understand what skills and competencies these opportunities develop in order to create a portrait of an engineering entrepreneur.

Conclusion

This study demonstrates that the engineering education ecosystem offers a variety of entrepreneurial opportunities, such as double-degree programs designed and developed in collaboration with business schools, entrepreneurial initiatives within postgraduate programs, entrepreneurial engineering and entrepreneurial minors, and various entrepreneurial engineering subjects/units. Educators and researchers can use the results of this study to develop a holistic understanding of the types of entrepreneurial initiatives within the engineering curriculum. It can also be used when designing entrepreneurial initiatives for engineering students or when comparing own entrepreneurial approaches to existing ones.

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