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Integration of Entrepreneurial concepts into Engineering degrees: A Systematic Literature Review

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ABSTRACT

CONTEXT

It has been recognised by numerous education researchers that engineering students can benefit from some exposure to entrepreneurship education. While integrating entrepreneurial concepts into an engineering degree is not new, it is worthwhile investigating how entrepreneurial activities/tools facilitate engineering students in developing an entrepreneurial mindset.

PURPOSE OR GOAL

The purpose of this study is to identify educational practices used by practitioners (academics) while integrating entrepreneurial concepts for engineering students. This paper highlights the common teaching and learning practices that have been employed to focus on fostering entrepreneurship in engineering students.

APPROACH OR METHODOLOGY/METHODS

A systematic literature review is conducted to investigate the current trend of using entrepreneurial tools and concepts within engineering education curricula. The review followed the reporting protocol of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Flow diagram. A total of 821 articles was initially obtained from six relevant databases. After applying specific inclusion and exclusion criteria, full-text versions of 71 articles were downloaded for review. 48 suitable articles relevant to the research objectives were selected for the final analysis

ACTUAL OR ANTICIPATED OUTCOMES

The key outcome of this study is the demonstration of educational practices that are used to incorporate entrepreneurial concepts into engineering degrees. The findings provide the current application of the major entrepreneurial practices in engineering degrees.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Upon analysis of the selected papers, this study outlines the current trend of educational practices that utilises entrepreneurship education in engineering degrees. It also informs and provides some guidelines to academics to consider different entrepreneurial activities while designing their engineering courses to foster entrepreneurial mindsets.

KEYWORDS

Engineering education, educational practices, entrepreneurship.

Introduction

Engineers today need to be equipped with a broad range of skills and knowledge due to the emergence of new technological innovations (Baruah, Ward & Jackson 2019). Beyond having a strong engineering background, an adequate understanding of the business environment is essential in order to identify market opportunities, develop product ideas or work in multidisciplinary teams (Creed, Suuberg & Crawford, 2002). In order to achieve these objectives, researchers and learning designers propose to design new entrepreneurship courses tailored for engineering discipline and focus on the development of an invaluable skill-set related to intuitive decision making or creative problem solving (Bodea et al. 2015; Baruah, Ward & Jackson 2019). Kuartko (2005) viewed entrepreneurship as an integrated concept that encourages an entrepreneurial idea to become a commercial success. Most importantly, it facilitates students to become more self-reliant (Sarnin, Naim & Idris, 2019; Clerk, 1892) and equips them with the necessary skill, knowledge and attitudes in order to achieve their preferred goals (Hamouda & Ledwith 2018).

Entrepreneurship education is commonly defined as the educational process that influences individuals' attitudes and behaviour towards entrepreneurial activities. It has been widely recognised by academics that entrepreneurship contributes much more than the creation of a business or employment (Mwasalwiba, 2010; Hamouda & Ledwith 2018). Henry et al., (2005) indicated that entrepreneurship programs instill self-confidence in the graduates' entrepreneurial abilities and test the commercial viability of an idea in addition to improving employability and developing a wide range of skills and knowledge (Hamouda & Ledwith 2018). Costin, O'Brien and Slattery (2018) also emphasised the significance of "social realities" that the students experience through entrepreneurship education that makes them more self-aware in the business world. Baruah et al. (2019), highlighted the absence of consistent and effective guidelines of entrepreneurial teaching curriculum for engineering students. Lassen and Nielsen (2011) stated that engineering students must be trained by academic institutions in areas such as creative problem solving and innovation through focusing on communication, teamwork and self-assessment. João and Silva (2020) also noted that the entrepreneurial mindsets of the students can be supported through the academic curriculum and extracurricular activities.

Engineering has a significant impact on driving economic growth and supporting national economies worldwide (Burnett et al. 2021). Developing an entrepreneurial mindset is, therefore, imperative for engineering graduates to ensure its continuance as a guiding element for economic prosperity (Commission of the European Communities 2006 as cited in Mäkimurto-Koivumaa & Belt, 2015). Entrepreneurial concepts have been infused in engineering or technology-focused curricula for at least more than two decades (Shuman et al. 2002; De Graff & Ravesteijn 2001). However, it is still challenging to understand the core benefits these approaches can offer to engineering students due to conflicting needs of gaining technical knowledge and developing an entrepreneurial mindset (Mäkimurto-Koivumaa & Belt, 2015; De Graff & Ravesteijn 2001). As a result, a significant increase in the academic literature on entrepreneurship education has been noticed over the past decade (Miranda et al. 2020). Some significant contributions have been made through funded entrepreneurial programs by The Kern Entrepreneurial Engineering Network (KEEN) and Lemelson Foundation as well as the scholarly contribution of the Entrepreneurship and Innovation Division of the American Society for Engineering Education (Huang-Saad et al. 2020; Miranda et al. 2020). One fundamental theme that arises from these works is the development of more entrepreneurial-minded engineering students by integrating entrepreneurship concepts into their learning processes (Shekhar & Huang-Saad 2019; Duval-Couetil et al. 2016). Current teaching practices in entrepreneurship education involve a wide range of activities and programs such as developing a business plan, business simulation, lectures, case studies, guest speakers and role models (Mani 2021; João & Silva 2020; Solomon, 2007; Wilson et al., 2007). Within this context, a broad understanding of the current entrepreneurial education practices for engineering students is imperative. However, due to the lack of a clear understanding of the profile of an entrepreneurial engineer, as well as the lack of clear requirements and accreditation criteria for entrepreneurial courses in engineering, educators use a large number of educational practices to foster

entrepreneurship in engineering students. In this study we aim to provide a summary that demonstrate the state of entrepreneurial education in the field of engineering focusing on educational practices.

This study, therefore, has utilised the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Flow diagram from Moher et al. (2009) to identify and review the published literature discussing the integration of entrepreneurial concepts in engineering education curricula and highlight the common teaching and learning practices that stimulate the entrepreneurial mindsets of engineering students. In achieving this objective, the two research questions are formulated: a) What is the current state of literature that examines entrepreneurship learning practices for engineering students? B) What are the common entrepreneurial teaching and learning initiatives employed in the engineering discipline?

Section II of the paper explains the methodology used in the study, followed by results in section III. Section IV provides a discussion of the results and Section V includes the implications, limitations and conclusion of the study.

Methods

A systematic literature review was conducted by following the reporting protocol of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Flow diagram from Moher et al. (2009). The process of selecting pertinent articles is arranged in three steps: initial search, selection and review as shown in Figure 1.

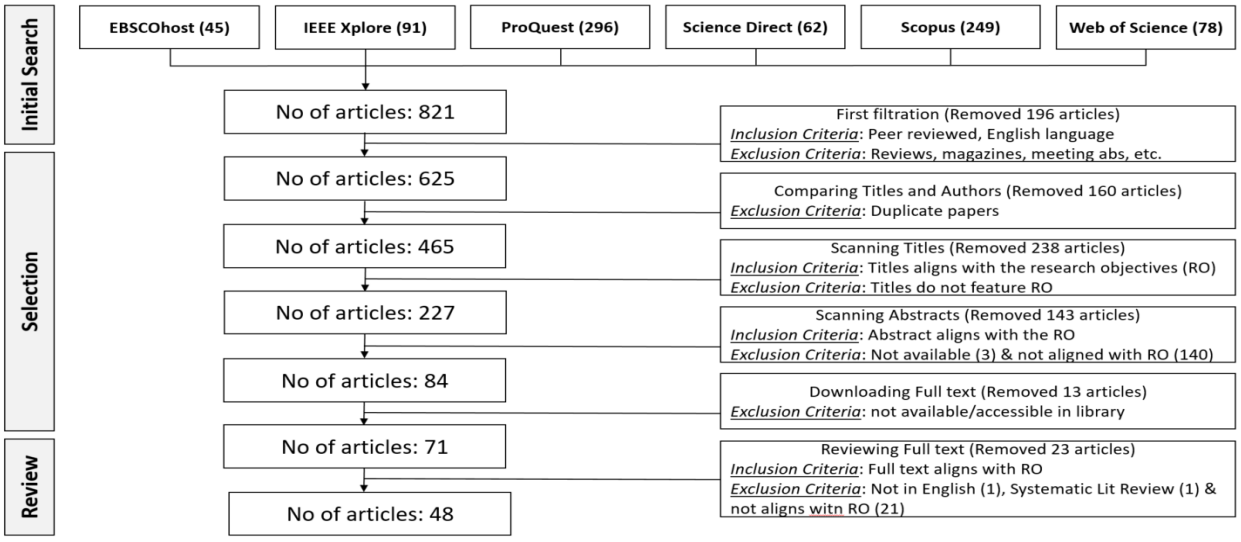

Figure 1: PRISMA Flow Diagram (articles searching and selecting process)

Initial Search

The initial search was conducted using specific search terms ‘engineering education’, ‘business’, and ‘entrepren*’ across the most commonly used databases EBSCOhost, IEEE Xplore, ProQuest, Science Direct, Scopus and Web of Science, between March and April 2022. Multiple iterations of the search was executed. The last search was run on 3rd April 2022. After applying these search terms, 821 articles were obtained from the specified databases as shown in the figure below. This result was exported to MS Excel and was uploaded to Google Spreadsheet to share with co-authors.

Selection & Review

First selection method (inclusion criteria) was to include only ‘peer reviewed’ and written in ‘English’ language articles. In this process, we have excluded articles which are published as review articles, magazines, meeting abstracts, and editorials from most of the databases. This process removed

196 from the initial result of 821 articles. Subsequently, all the articles were checked for duplicates by sorting them from their titles and authors. 160 duplicates were excluded from this step. The first two authors scanned the titles of 465 articles together and removed 238 of them, as they were not relevant for the topic of our investigation.

The next approach we undertook was scanning abstracts of the remaining 227 articles. Abstracts for the 3 articles listed were not available and hence removed. The remaining 224 abstracts were voted for inclusion or exclusion. In this process, 84 articles were selected for further processing. While downloading full-text versions of selected articles, 13 of them were not available in the databases through the library and were subsequently removed. 71 full-text articles were downloaded. During this process, we found one of them was written in a non-English language, another conducted a systematic literature review and hence removed and the other 21 are found to be not relevant for the objective of this study and hence removed. Finally, 48 articles were selected for thorough review in this study. Results from these articles are presented in the next section.

Results

The final 48 publications were read thoroughly and reviewed in depth to investigate the integration of entrepreneurial concepts in engineering education curricula. The final list of publications is segregated according to the place of study (country) to show how these publications are limited to only a few specific countries; 50% of those selected articles were studied in and about the United States of America (USA), the rest were distributed in 19 other countries as shown in Table 1 below:

Table 1: Distribution of articles geographically (as per countries)

Country of study	No. of studies per country	Total No. of studies	%
USA	24	24	50%
Malaysia, Netherland, Portugal, Romania, Turkey	2	10	21%
Brazil, Canada, Chile, Cyprus, Denmark, England, Finland, India, Ireland, Jordan, Norway, Singapore, Spain & Sweden	1	14	29%

The selected articles were also categorised based on whether the study aimed at a specific level of engineering degree, either undergraduate, postgraduate or both. The majority of them (28 out of 48) articles specified that their study is for or about an undergraduate degree and a few (4 out 48) focused on postgraduate students and some (5) of them mentioned that their study is relevant to all levels of a university degree. However, 11 out of 48 articles did not specify the level of students. Table 2 shows the number of articles that specified the different levels of engineering degrees:

Table 2: Level of engineering degrees

Degree	No. of studies	%
Undergraduate / Bachelor	28	58%
Graduate / Master	4	8%
Both (Bachelor, Master and others)	5	11%
Not specified	11	23%

The earliest date of publication among the selected articles in regards to how entrepreneurship courses were introduced in engineering education is 1996. From that date till recent publications in 2021, the distribution of articles across the last 25 years is presented in the bar chart (Figure 2) below. About two third of the publications were in the last six years (2015 to 2021) and the biggest number of articles (i.e. six) was published in the year 2019 followed by five publications in the year 2016 from the selected list.

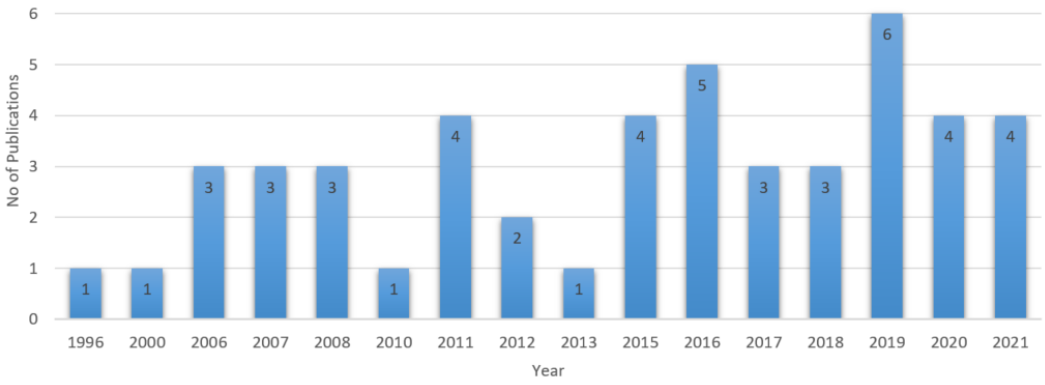

Figure 2: Distribution across publication years

Most of the selected articles (37 out of 48) were published in conferences, nine of them were journal articles and only 2 were published as book chapters. The proportion of conference, journal articles and chapters is shown below in Table 3.

Table 3: Distribution of publication sources

Published in	No. of studies	%
Journal	9	15%
Conference	37	81%
Chapter	2	4%

The primary objective of this review is to identify several educational practices used by practitioners (academics) while integrating entrepreneurial concepts for engineering students. Not all articles from the selected list mentioned educational practices as some were solely focused to investigate the entrepreneurial intentions and mindsets of students from their programs (Sababha et al. 2021; Barba-Sanchez & Atienza-Sahuquillo 2018; Yildirim et al. 2016; Hallam et al. 2008). We define education practices as the wide range of activities, policies, approaches and methods that can help to achieve changes in student thinking, behaviour or attitude. Some articles were practice-oriented and indicated their educational practices. Based on content analysis, a list of educational practices is extracted from those articles and the number of corresponding articles is specified in Table 4 below:

Table 4. Educational Practices for entrepreneurship education in engineering degrees

S. No.	Educational Practice	No. of Articles
1	Business Plan	31
2	Teamwork	30
2.1	Multi/Inter-disciplinary teams	13
3	Project Based Learning (Market Analysis, Revenue model, etc.)	13
3.1	Case study based	10
4	Pitch / Presentations	11
4.1	Venture / Start-up competition	9
5	Prototyping	7
6	Lean Start-up (Business Model Canvas, Minimum Viable Product etc.)	5

7	Capstone	4
8	Internship	3
9	idea Lab / hub / Club	4
10	Guest Speakers	4
11	Patenting / IP course	4
12	Design Thinking	3
13	Business Simulation	2
14	Mentoring/Coaching	2
14	Seed capital or Funding	2
16	Showcase / Exhibition / Fest	1
17	Creativity Camp Design	1
18	Extra-curricular Activities	1
19	Career planning	1
20	Tool like clickers or podcasts	1

In academic settings, many educational practices and tools are available to inspire students to learn entrepreneurial mindsets while undertaking a university degree. After analysing the selected lists, we identified that preparing a business plan is the most prevalent practice while integrating entrepreneurial content in engineering education as shown in the above table. Almost two third of the selected articles (31 out of 48 articles) mentioned that preparing a business plan is one of the activities they implemented. Similarly, most of the articles prescribed that teamwork is paramount for entrepreneurship education. 30 of the articles from the list warranted that students working in groups is important for the context of entrepreneurship. Some were even more assertive about having multi or interdisciplinary groups from different faculties for better results in entrepreneurship education. Petersen et al. (2012) discussed how collaborating between engineering, business and liberal arts is helpful for the better result for students. A similar view was portrayed by Porter et al. (2015) to involve students from engineering, business and architecture in collaborative projects.

Furthermore, 13 out of 48 articles pointed out that project-based learning has been used to integrate entrepreneurship into engineering education. Active learning approaches like guest speakers, elevator pitches, mentoring, and case studies have been used (Zappe et al. 2012). Many other articles pointed out that case studies have been used in their classes with a series of activities. For example, Looney and Kleppe (1996) introduced an entrepreneurship course for electrical engineering degrees by giving students to work on some real works from the industry. It is reported separately as the number of articles was counted based on the actual terminologies ‘project-based’ and ‘case studies used within the text of those articles.

The lean start-up method for developing a product or business has also been applied as educational practice while infusing entrepreneurial mindsets for engineering students. Exploring the market, creating a minimum viable product (MVP), using a business model canvas (BMC) and pitching are some of the steps in this method that have been practised (Silla Jr. 2021; Porter et al. 2015; Shekhar et al. 2017). Group or individual presentations is another common practice mentioned with the integration of competition or festivals. Prototyping is another practice that seemed to be applied to technical students, however, only 7 articles mentioned that it has been used in their practice. Intellectual property courses, more specifically patenting, are also discussed as one of the common educational practices for engineering students (Hallam et al. 2008; Richards 2007: Grimheden 2007; Zappe et al. 2012). Several studies pointed out the importance of entrepreneurial context towards

the end of the degree and introduced it in their capstone subjects (Favaloro et al. 2018; Zappe et al. 2012; Davis & Rose 2007; Rufe et al. 2006).

Discussion

The results of this study support and update the statement provided by Huang-Saad et al. (2020) that practice-based studies dominate in the field of entrepreneurial education and focused on developing an entrepreneurial mindset in engineering students. According to Karimi et al. (2010), entrepreneurial education should be learned by "immersing" in real-life experiences. That is why entrepreneurial academics are focused more on exploring the practices and experiences that are able to immerse students in the real-life context and live through the experience of entrepreneurship rather than investigating the connections between specific activities and learning outcomes that students should possess after completion of the educational activities. Therefore, the state of literature is characterized by the importance of practice-based holistic learning experiences. This is confirmed by the prevalence of practice-oriented conference papers in the scope of literature and the lack of goals in these works aiming to form unified theoretical models conceptualising the profile as well as essential competencies that future entrepreneurial engineers should possess. In this regard, it is important to consider the trend of holistic and practice-oriented approaches that reflect real-life experiences in developing entrepreneurial programs.

The dominance of practice-oriented research in entrepreneurship engineering literature also forms specific educational and research trends in which academics, researchers and learning designers try to "look over" different practices and test their effectiveness. This approach leads to the formation of various approaches, practices and tools that are used to foster an entrepreneurial mindset in engineering students. The variability of approaches and practices is also due to the lack of a clear consensus on what components, principles, and terms should be included in entrepreneurial programs in order to make students more entrepreneurial, innovative, proactive, etc. (Kirby, 2004; Henry et al., 2005). In this regard, when developing entrepreneurial programs for engineering students, it is essential to take into account the variability of approaches and the lack of consensus in terms of the educational process and the portrait of an entrepreneurial engineer.

The current state of the literature demonstrates the trend toward moving away from business activities (e.g financial plan or business model) in educating entrepreneurial engineers toward more product-oriented and project-based approaches. Additionally, most of the reviewed programs and approaches use experiences that include creativity, problem-solving and opportunity recognition components required to create a product or a venture (project) which are among the fundamentals of entrepreneurship (Robinson & Stubberud, 2014; Schuelke-Leech, 2020). According to Kingon et al. (2002), business and entrepreneurial courses or programs should emphasize different topics. In this regard, when creating programs, it is important to pay attention to the practices formed and offered by entrepreneurial literature.

Conclusion

There are several trends that demonstrate the state of the literature in the field of entrepreneurial education for engineering students such as practice-based learning, variability of practices and lack of a clear consensus in terms of the learning goals and principles of the educational process, as well as the shift from classical business approaches towards more product or service (e.g., MVP) and project-oriented educational approaches. Educators, learning designers and coordinators should take into account these trends, as well as consider the contextual characteristics of engineering practice to design and deliver effective educational programs aimed at fostering an entrepreneurial mindset in engineering students.

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