

ENGINEERING EDUCATION AND ENTREPRENEURSHIP EDUCATION: COMPLEMENTARITY, OPPORTUNITIES AND CHALLENGES

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Abstract: Due to the downturn of global economies, high global unemployment rates, and dwindling economies at country specific levels, the increasing demand for soft skills, engineering education has shifted from the typical and traditional technical paradigm to a multidisciplinary approach. This has presented some challenges for engineering education. One of the challenges or opportunities is the inclusion of entrepreneurship education into the technical engineering curriculum. Although engineering graduates have the technical education and expertise, they are expected to become supervisors, managers and business owners. As such they are entrusted with resources (human, material and financial) to efficiently utilise and meet the goals of their respective organisations. Also, during the period of their study, engineering students may discover innovative ideas or design new experimental prototypes, which require further development and upscaling into full products that are ready for marketing. These require incubation, management and entrepreneurship skills. Therefore, there is the need to include entrepreneurship education in university engineering curricula. However, there is still an unending debate among engineering institutions and researchers on whether to include, and/or the extent of the inclusion of entrepreneurship and management modules in the engineering curricula. Furthermore, students in engineering entrepreneurship programmes gain insights into designing for end users working in, and managing interdisciplinary teams, communicating effectively, thinking critically, understanding business basics and solving open-ended problems (Byers, Seeling, Sheppard, & Weilerstein, 2013). Therefore, this study was designed to discuss the role entrepreneurship education plays in engineering education. The study first documented the existing and available literature on entrepreneurship education and engineering education, followed by examining the engineering students' perceptions on entrepreneurship education in their engineering education curricula. The results indicated that, globally, many engineering institutions have in different ways infused entrepreneurship education into their curricula. However, research findings and participating engineering students have opposing views on the benefits and impacts of entrepreneurship education on future job prospects or owning self-business. The result of this study has implications for schools of business and engineering education.

Keywords: Engineering Education, Entrepreneurship Education, Engineering Curriculum, Innovation, Engineering Intention

1. INTRODUCTION

Due to the current global economic crisis and its associated high unemployment rates and dwindling economies, there has been a need to critically retool engineering education to mitigate the socio-economic challenges of the day for developing, as well as developed economies. The knowledge and skills required by the present and future jobs are changing, and consequently, the education system at all levels must respond and adapt to the new challenges (Grecul & Dene, 2017). Therefore, there has been an increasing call to shift engineering education from the typical and traditional technical paradigm to a multidisciplinary approach. This has presented both challenges and opportunities for engineering education. One of the challenges or opportunities is the inclusion of entrepreneurship education into the technical engineering curricula. Entrepreneurship is viewed as the capacity and willingness to develop, organise and manage a business venture along with any of its risks to make a profit. The most obvious example of entrepreneurship is the starting of new businesses (Karim, 2016). Entrepreneurship education is “the content, methods and activities supporting the creation of knowledge, competencies and experiences that make it possible for students to initiate and participate in entrepreneurial value creating processes” (Nair, Sundar, & Paramasivam, 2020).

Globally, Innovation and entrepreneurship education are increasingly becoming important to create jobs or make university graduates more efficient and effective managers or owners of start-up businesses. Students in entrepreneurship programmes gain insights into designing for end users working in, and managing interdisciplinary teams, communicating effectively, thinking critically, understanding business basics and solving open-ended problems (Byers, Seeling, Sheppard, & Weilerstein, 2013). Engineering students may also discover innovative ideas and develop prototypes which require further development into a full product, ready for marketing. These require product incubation and packaging, which are part of entrepreneurship education. Therefore, many countries have recognised the need to include entrepreneurship education in Science, Technology, Engineering and Mathematics (STEM) programmes. “The gap between real-life situations and the classroom theories and concepts can be bridged with the help of entrepreneurship education for students with different specialised fields. Bringing students from non-business fields closer to the business school is the approach of some institutions that aim to educate students in an entrepreneurship classroom characterised by diversity” (Grecul & Dene, 2017). The ability of engineering institutes to train quality manpower is not enough; their educational programs must be geared towards enhancing the

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students' creativity, original thinking, leading qualities and initiatives. These require entrepreneurship training alongside engineering education.

However, despite the above recognition, there is still an unending debate among engineering institutions on whether to include, and/or the extent of the inclusion of entrepreneurship and management modules in their various engineering curricula. Some institutions are still hesitant to include entrepreneurship education in STEM programmes and others are debating on the degree and nature of inclusion, either as compulsory, electives or optional courses. There are still those who are debating on whether the courses should be run by their business schools or in engineering faculties (Shekhar & Huang-Saad, 2021).

The current study is designed to discuss the role entrepreneurship education plays in engineering education. The study first documented the existing and available literature on entrepreneurship education and engineering education. This was followed by examining the entrepreneurship programme offered by the School of Business and Professional Development (SBPD) in Botswana International University of Science and Technology (BIUST).

The literature review was centered around the following four general thematic areas;

- i. The importance of entrepreneurship education in engineering programmes or curricula.
- ii. The extent of inclusion of entrepreneurship education in engineering education.
- iii. Opportunities and challenges of entrepreneurship education into engineering education curriculum
- iv. Engineering Students' perceptions on the inclusion of entrepreneurship models in their study pack.

2. METHODOLOGY

This research used published and available literature on the topic. One hundred and fifty publications were downloaded. There were 50 conference papers and 100 journal articles. These downloaded conference proceedings and journal articles were carefully scrutinised based on their appropriateness and relevance to the research topic and the four thematic areas stated above. Finally, only nine papers from conference proceedings and 40 refereed journal publications were selected. While some covered more than one thematic area, there were others that addressed only one of the thematic areas.

3. FINDINGS

3.1. The importance of entrepreneurship education in engineering education

Globally, the importance of entrepreneurial training in engineering education has been widely accepted by most universities. This acceptance comes because of the need to develop a wide range of soft skills such as innovative, creativity, and problem-solving skills to assist future engineers to succeed in today's technology-driven economy (Dominguez, et.al, 2021). Increasingly, graduates are expected to adapt their complex problem-solving skills to align with the modern-day multidisciplinary practices of engineering and know how to integrate their science and engineering skills training to enhance industrial and leadership practices (Creed, Suuberg, & Crawford, 2002). This implies that current day engineers must be able to effectively communicate, work in multidisciplinary positions, solve complicated management problems, while maintaining a sustainable, cultural, social and economic environment (Dominguez, et. al, 2021). The inclusion of entrepreneurship education in engineering education curricula is hinged on the above premise. "Entrepreneurship education is one of the platforms that the engineering institutions have adopted to expose students to practices and mindsets deemed critical for their growth and success upon graduation" (Shuman, et al., 1999).

Entrepreneurship education programs have a positive impact on improving attitudes towards self-employment amongst engineers, and it is no longer enough to come out of school with a purely technical education; engineers need to be entrepreneurial to understand and contribute to the context of market and business pressures (Byers, et. al, 2013). Entrepreneurship education should be a pre-requisite for engineers who start companies soon after graduation. It enhances their experience in product design and development, prototyping, technology trends, and market analysis (Neck & Greene, 2011). These skills are just as relevant for success in established enterprises as they are in start-ups. It has been shown that students with entrepreneurial training who join established firms are better prepared to become effective team members and managers and can better support their employers as innovators (Duval-Couetil, Reed-Rhoads, & Haghighi, 2012), and it teaches engineering students the knowledge, tools, and attitudes that are required to identify opportunities and bring them to life (Kishore, 2021).

The inclusion of entrepreneurship education in engineering training programmes can lead to the production of graduate entrepreneurs who can contribute to a country's competitiveness, by facilitating or creating new jobs and engaging in the development of innovative products and services (Facey-Shaw, et al., 2019). Esparragoza (2009) suggests that through fostering entrepreneurship, creativity and other skills, engineers

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have the potential to develop new technology which is key for economic growth and innovation. Facey-Shawet. al, (2019) state that entrepreneurship education positively contributes to entrepreneurial intention, which in turn motivates engineering graduates to start businesses and improve the image of entrepreneurship as a career option.

Jarrar & Anis (2016) posited that the integration of entrepreneurship education into the engineering curriculum can have a significant positive impact on design, investigation, problem analysis, life-long learning, communication skills, individual and team work, and economics and project management. Vieira and Rodrigues (2014) indicated that entrepreneurship education creates awareness in engineering students such that its inclusion can broaden their career prospects and choices, while also recognising that entrepreneurs have a positive image in society. It is considered a fostering factor of entrepreneurial intention and could raise the awareness, knowledge, and abilities necessary to start a business (Draksler & Sirec, 2021). Entrepreneurship bridges the gap between real-life situations and the classroom theories and concepts.

Students who take part in entrepreneurship programmes at undergraduate levels gain insights not available from traditional engineering education, such as understanding and designing for end users, working in and managing interdisciplinary teams, communicating effectively, thinking critically, understanding business basics, and solving open-ended problems (Kishore, 2021). The author also confirms that Entrepreneurship education and programmes will not only aid the institutions to create industry-ready entrepreneurs, but also steer the students towards being independent while securing their careers, which accentuate the need for self-dependence as well, while simultaneously catering to accelerate a country's economy (Kishore, 2021). Entrepreneurial intentions serve to mitigate the challenge of job scarcity by promoting self-employment and fostering the establishment of new ventures (Bomani, Gamariel & Juana, 2021; Mambali, Kapipi, & Changalima, 2024; Neck & Greene, 2011). Yi and Duval-Couetil (2018) reported that entrepreneurship education leads to the motivation, creation and solution, of personal interest and managerial effectiveness among engineering students.

Hassan, et al, (2017) stated that creativity, communication skills, motivating and managing employees, leadership, high ethical standards and strong sense of professionalism, dynamism, agility, resilience and flexibility and lifelong learning are skills that can be gained from entrepreneurship and other inter-disciplinary courses. The Global Entrepreneurship Monitor (GEM) study showed that entrepreneurship has the potential to create jobs and generate wealth in a nation's economy, and that economic growth and development are linked to entrepreneurship (Barba-Sanchez & Atienza-Sahuquillo, 2018; Barba-Sanchez & Atienza-Sahuquillo, 2012), and Thurik, Carree, van Stel, & Audretsch, (2008) confirm that there is a close relationship

between self-employment and reduction in unemployment rates during periods of economic recession, and the establishment of Technology-Based Companies (TBCs). A comparative study between graduates whose course focusses on entrepreneurship and graduates who do not focus on entrepreneurship courses showed that graduates focusing on entrepreneurship were employed within organisations on a full-time basis and were more satisfied with their employment opportunities (Cho & Lee, 2018). Students receiving entrepreneurial training before the beginning of their professional careers have favourable future career prospects (Creed, Suuberg, & Crawford, 2002). According to Holzmann, Hartlieb, and Roth (2018) entrepreneurship education helps engineering entrepreneurs to increase the speed of knowledge transfer from engineering education to the public, the ease of access to novel technologies, the perception of entrepreneurs and the connotation of entrepreneurship within a society. It also increases the ease of hiring and retaining well-trained staff, the degree of bureaucracy to start a business, the size and proximity of expert networks to support information and knowledge exchange, and access to financial capital in the individual founding phases. Furthermore, it helps university students to prepare for future job uncertainties as job requirements change in response to technological advancements; encourages creativity, innovation and collaboration; improves students' problem identification and problem-solving skills (Holzmann, Hartlieb, & Roth, 2018).

It is evident from the research findings of Adamec and Hrmo (2023) that entrepreneurship education supports the motivation of youths to actively create an entrepreneurial environment, and it intensifies the link between business and academia. Miller et. al. (2011) found that students who participate in entrepreneurship education programmes are 73 percent more likely to start started a new company, 23 percent more likely to create new products or services, and 59 percent more likely to have high confidence in leading a start-up.

The above literature shows that the inclusion of entrepreneurship education in the engineering education programmes improves the entrepreneurial skills and mindset change for engineering graduates, improves the job prospects or create jobs and makes them to become efficient and effective employees.

3.2. The integration of entrepreneurship education into the engineering curriculum

The importance of entrepreneurship education justifies its inclusion in engineering education curricula, which makes engineering students work in interdisciplinary programmes. "Working in interdisciplinary contexts demands new competences, and requests for 'T-shaped' engineers. T-shaped-engineers refers to those who have deep

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knowledge in one engineering discipline and general knowledge and competences that help them form bridges with other disciplines” (Route, Holgaard, & Kolmos, 2024).

Various approaches have been used to integrate entrepreneurship into the curriculum for technical students, including specialised courses, for example, Technology Entrepreneurship for Engineers and Computer Scientists (Facey-Shawet. al 2019). 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 (Joao & Silva, 2020). The integration of entrepreneurship education into the engineering curriculum requires optional programmess in leadership and innovation spanning several courses including seminars and presentations on entrepreneurial experiences (Doboli, et. al, 2014).

Recommendations to foster entrepreneurship among engineering university students include start-up exhibitions of successful entrepreneurs as role models, workshops on idea generation and business plan creation, and inter-university business plan competitions (Barba-Sanchez & Atienza-Sahuquillo, 2018). However, programmes can vary according to the objectives required by individual universities (Duval-.Couetil, Reed-Rhoads, & Haghighi, 2012). Certain programmes will focus on increasing entrepreneurship concepts, while others will focus on innovation and its aspects (Duval-Couetil et al., 2016). For the integration of entrepreneurship and innovation in engineering education to be successful, faculties will need to change their viewpoint and be willing to contribute or at least agree to modifications in the engineering curriculum (Byers, et.al, 2013).

In some universities entrepreneurship is taught within the engineering faculties The other way is either the entrepreneurship courses are taught within the engineering faculties, as practised in Havard University or taught in the School of Business as in Massachussettes Institute of Technology (MIT) (Hassan etal., 2017). The authors also outlined the pedagogical methods of incorporating entrepreneurship into engineering education. The first is by developing technical entrepreneurship case studies that are designed to be integrated into existing engineering fundamental courses. These case studies are intended to provide engineering students with entrepreneurial role models and to show the future engineers how those models require them to use their knowledge of a specific engineering topic covered in typical undergraduate courses to create successful business ventures. In a related study, Pradhana, Khan and Litvinova (2022) confirmed that, in order of priority, engineering students would like to learn how to prepare business plans, work in teams, be exposed to inter-disciplinary items, to be engaged in project-base learning, work on case studies, pitch and present business ideas, be engaged in new venture or start-up competitions, internmships,

listen to guest speakers, coaching or mentoring, and seek seed capital (Pradhana, Khan, & Litvinova, 2022).

3.3. Students' perceptions on the integration of entrepreneurship education in engineering curriculum

Various research reports show that numerous universities have adopted various forms of entrepreneurship education programmes which are typically offered as either electives, optional or compulsory courses. To create suitable programmes that will encourage students to seek out entrepreneurship education programmes, it is expedient to understand the factors that influence participation in such a programme. Therefore, this section examines engineering students' perceptions of the inclusion of entrepreneurship education courses in their curricula.

A study by Facey-Shaw et. al (2019) reports that about 71 percent of science and engineering students in a Jamaican university were interested in starting a business and greatly considered the entrepreneurship courses useful should they start a business. When asked to examine their involvement in the student-based entrepreneurship club and the business model competition hosted on the university campus, it was revealed that only six percent of students attended the club and approximately 15 percent participated in a business model competition session, indicating that outside of the formal course on entrepreneurship, these students do not appear to be gaining additional information on becoming entrepreneurs through these informal activities.

Mosly (2017), and Souitaris, Zerbinati and Al-Laham (2007) found that inspiration proved to be most strongly associated with an increase in entrepreneurial intention, particularly among undergraduates who are very unlikely to start a business immediately after graduation. The authors concluded that if the target is to increase the number of students who become entrepreneurs, then the inspirational aspect of the program must be purposeful. The report also provides evidence that entrepreneurship education can have a positive impact on the, entrepreneurial mindset and activity.

According to Duval-Couetil, Reed-Rhoads and Haghighi (2012) a very high percentage of engineering students who have done one or more entrepreneurship courses agree that entrepreneurship education broadens their career path prospects and choices (82%) against 69% of students who have taken no entrepreneurship courses. They are also more interested in becoming entrepreneurs (59%) than their counterparts (34%) and have an idea for a business product or technology (46% against 32%). Although students in both groups were most interested in working for a

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medium or large-size business, or attending graduate school, there were significant differences between the two groups of students in terms starting their own businesses or working for a small business or startup company (43% against 34%), but both groups were against working for a non-profit organisation or serving in the military (Duval-Couetil, Reed-Rhoads, & Haghighi, 2012). Students who perceived themselves as having entrepreneurial experience reported that they possessed entrepreneurial attributes and skills such as creativity, ambition, determination, passion, and confidence in decision making.

According to Taks et al. (2014) students perceived entrepreneurship studies as a first step to self-directed learning, a preparation for work life, a path to possible self-employment, and a context for developing leadership and responsibility for group achievement. Shekhar and Huang-Saad (2021) added that students' confidence in their communication and public speaking skills and self-employment as opposed to working for an established company informed their decision to register for entrepreneurship education programmes.

Udo-Imeh et al. (2016) found out that curriculum and course contents are critical to the achievement of course outcomes, and Ozaralli & Rivenburg, (2016) identified that theory-based approach to entrepreneurship teaching and the non-involvement of practical entrepreneurs are responsible for the low interest in, and poor perception of students to entrepreneurship in Turkey.

3.4. Challenges

Although the importance of entrepreneurship education has been emphasised and has led to many countries and universities including it in their various engineering programmes, there is an inconclusive report on the evaluation of the potential benefits of teaching entrepreneurship to engineering students. The degree to which entrepreneurship plays a role in contemporary engineering students' academic programmes or career paths is largely unknown (Duval-Couetil, Reed-Rhoads, & Haghighi, 2012). Bilau and Santos (2023) stated that it is likely that obstacles may arise when the university is divided into schools and their respective departments work with significant independence. The lack of cooperation or coordination between schools or departments can be a compromising obstacle for the integration of entrepreneurship education into engineering programmes. When the change is driven by an external recommendation, the team responsible for modifying the curricula may not be equally committed since the introduction of the new curricula unit often requires either the suppression or merging of core courses within the programme to satisfy the total credit requirement of the engineering programme (Byers et al., 2013), and in most schools, faculty members who teach entrepreneurship have never had any contact

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with the realities of the business world; hence, their handling of the entrepreneurship courses may dampen students' interests (Bilau & Santos, 2023).

Different researchers emphasised the difficulties of evaluating the benefits or importance of teaching entrepreneurship. In their research, Colette, Hill and Leitch (2005) stated that there is not much empirical evidence to show that the completion of entrepreneurship and management courses increases an individual's chances of starting a business. In a similar study, Matlay (2005) stated that the real contribution that management and entrepreneurship courses have on postgraduate entrepreneurship activities remains unclear, and various authors such as Barringer, Jones and Neubaum (2005), Fayolle, Gailly, & Lassas-Clerc, (2006); in Barba-Sanchez and Atienza-Sahuquillo (2018) have corroborated that the degree to which entrepreneurship plays a role in contemporary engineering students' academic programs or career paths is largely unknown. Although more engineering students are being exposed to entrepreneurship education, minimal research has examined engineering students' attitudes toward it, its impact on their learning, or professional competence. This is not surprising given that the integration of entrepreneurship in engineering is a relatively new effort, where definitions of what it means to be entrepreneurial within an engineering programme as well as programme models vary greatly (Standish-Kuon & Rice, 2002; Duval-Couetil, Rhoads, & Haghighi, 2012). Even within the field of management, entrepreneurship education is considered by some to be a relatively new field, still engaged in conceptual and methodological debates (Brazeal & Herbert, 1999). For example, there is a lack of consensus on the degree to which entrepreneurship is a set of principles, terms, competencies, and skills that can be learned, versus a set of attributes that make one opportunistic, competitive, proactive, risk tolerant, autonomous and innovative (Caird, 1992; Henry, Hill, & Leitch, 2005; Kirby, 2004). The objectives and content of entrepreneurship programmes also vary widely, which leads Henry, Hill, and Leitch (2005) to state that the 'content of syllabi of courses developed by entrepreneurship scholars differs to such an extent that it is difficult to determine if they even have a common purpose' (Henry, Hill, & Leitch, 2005).

The teaching of entrepreneurial skills and entrepreneurial thinking requires the use of pedagogical methods that are not easy to apply in traditional educational environments and settings. Similarly, there is a perceived lack of academic staff to teach such subjects because they do not have the appropriate entrepreneurial experience (Adamec & Hrmo, 2023; Bilau & Santos, 2023). Also, in a situation where the teaching staff in the engineering school stick to the conservative paradigm that engineering students should only acquire technical knowledge, the collaboration of such teaching staff can potentially doom the curricula change to failure (Bilau & Santos, 2023). This

implies that the infusion of entrepreneurship education can be more facilitated when both engineering and business faculty members co-exist and plan it well.

Although research evidence highlights both the importance of entrepreneurship education and training during students' study periods, it also confirms that students' entrepreneurial intentions are influenced not only by the university environment, but also by their family background and the society in which they live. The fact that family environment and intergenerational learning have an impact on entrepreneurial aspirations is demonstrated by research findings from those of Kamanova, Pevna, & Rabusicova (2016a) and Rabusicova, Kamanova, & Pevna (2016b).

This section reveals that despite the importance of entrepreneurship education, its inclusion and implementation in engineering programmes is still clustered with challenges and problems that make it difficult to assess its positive impacts on graduate engineers.

4. SUMMARY AND CONCLUSION

The global challenges of economic crisis, followed by high unemployment rates and dwindling economies of both developed and developing economies have led to a paradigm shift in the way engineering education is taught. Several universities have switched from the traditional method of teaching to a new pedagogical approach which prepares engineering graduates for life after university. This article reviewed the relevant literature on the inclusion of entrepreneurship education into undergraduate engineering programmes. The review found that teaching entrepreneurship to engineering students has both opportunities and challenges. The opportunities include increased job prospects, start-up businesses, improved communication skills, ability to work in teams, and many others.

However, the extent to which these opportunities are attained by engineering graduates have not been established by researchers. Also, most of those teaching the courses do not have adequate entrepreneurial experience, and most business schools emphasise academic outcomes as opposed to the practical aspects as well as the promotion of soft skills. Therefore, extended research is required to assess graduate engineers' perceptions about the impact of entrepreneurship education on their postgraduate experiences.

5. FUTURE RESEARCH

There is need to follow-up on our engineering graduates to find out how entrepreneurship courses have assisted them to either find jobs or to start their own

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businesses. Further, there is the need to find out whether entrepreneurship courses made them any different from their counterparts from other universities in Botswana. Secondly, there is need to develop appropriate questionnaires to collect information from current students and faculty staff on their perceptions of infusing entrepreneurship courses in the engineering curriculum in Botswana International University of Science and Technology (BIUST).

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