

Innovation and Entrepreneurship in Engineering Education: Creating an Entrepreneurial Mind-set

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ABSTRACT

CONTEXT

The opportunities presented by generative AI and big data and other disruptive technologies will be more readily realised if engineers have an entrepreneurial mind-set that enables them to commercialise the associated market opportunities. Perceptions persist of engineers as people who are technically competent but with a poorly developed appreciation of value creation in engineering projects, despite many universities embedding entrepreneurship education into their undergraduate engineering curricula. This paper explores the embeddedness of innovation and entrepreneurship in engineering education across two engineering disciplines at a UK university and identifies opportunities for enhancing effective practice in this important area.

PURPOSE OR GOAL

The study explores approaches in entrepreneurship education for engineering students in tertiary level education. Two undergraduate engineering programmes at a UK university are reviewed to establish the pedagogic *modus operandi* employed for entrepreneurship teaching. The extent to which the development of an entrepreneurial mind-set can be prioritised in engineering undergraduate curricula is studied.

APPROACH OR METHODOLOGY/METHODS

The study employs document analysis to systematically examine how entrepreneurship is defined, the types addressed, and the teaching methods used in a UK university across business and management, communication and engineering disciplines. Two programmes from each subject area were analysed. By examining curriculum frameworks, syllabi, assessment methods, etc. researchers were able to identify implicit and explicit definitions of entrepreneurship, the diversity of entrepreneurial concepts introduced, and the pedagogical approaches utilised.

ACTUAL OR ANTICIPATED OUTCOMES

Preliminary findings suggest that engineering education focuses on equipping students with strong technical skills and engineering knowledge, with entrepreneurship viewed as a secondary skillset. By comparing two different engineering undergraduate courses, we identify opportunities to enhance the entrepreneurial capabilities of future engineers beyond the traditional design thinking, intellectual property and technology commercialisation. Practical suggestions of how to embed entrepreneurship education more effectively are provided.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Graduate engineers who have an entrepreneurial mind-set are very attractive to employers. This study argues that engineering educators should adopt a more integrated and holistic approach to the delivery of innovation and entrepreneurship in undergraduate engineering curricula.

KEYWORDS

Entrepreneurship education, entrepreneurial mind-set for engineering students, employability

Introduction

The advent of emerging technologies and their disruptive potential on a global scale offer unprecedented growth opportunities for the engineering and tech sectors. These growth opportunities will be much more readily realised if engineers have a well-developed entrepreneurial mind-set that enables them to identify, generate, and commercialise the associated market opportunities. Whilst many universities embed entrepreneurship education into their undergraduate engineering curricula, societal perceptions persist of engineers as people who are technically competent but with a poorly developed appreciation of value creation in engineering projects.

Background and Context

The Royal Academy of Engineering UK's National Engineering Policy Centre in its Engineers 2030 report advises that as artificial intelligence (AI) becomes more prevalent, the human decision-making required to help solve the complex global challenges and to help avert the mis-use of powerful technology becomes more critical. In addition to technical competence, the report calls for global responsibility in the engineering profession which encompasses behaviours and attitudes such as wisdom, empathy, reasoning, and advocacy for the natural world.

Since most engineers work in private sector enterprises they are expected to add value to the products and services that their companies provide to paying customers. The importance of entrepreneurship education within STEM disciplines (Science, Technology, Engineering and Maths) is widely accepted by the engineering community and by governments. Despite this, engineering educators in the UK have been slow to develop effective pedagogic approaches that embed the subject area as a mainstream topic in undergraduate engineering curricula, with many considering entrepreneurship education as an optional 'add-on' or co-curricular activity (Shekhar and Huang-Saad, 2019) rather than as a core activity. The framework proposed by Miranda et al (2020), based on 'being, acting and involving' is useful in redefining entrepreneurship in the context of engineering education and takes account of the work done by London et al (2018) in which twelve mindset outcomes and seventeen behavioural outcomes were mapped to the Kern Engineering Education Network's (KEEN) established 3Cs domains; namely curiosity, connections and creating value.

If the growth opportunities such as those offered by AI and generative AI (genAI) and other disruptive technologies in the future are to be realised, entrepreneurship education for engineers should be "integrated, not inserted" as proposed by Cummins et al (2021) so that engineering employers will have suitable talent pools of graduates who can work effectively in inter-disciplinary, cross-cultural and trans-national settings and who have the entrepreneurial skills to build successful businesses around innovation. Along with the technical competence there is an increasing emphasis, as noted by Ilyas et al (2024), on the human relation competences (e.g., interpersonal and communication skills) in performing those job tasks that require collaborative teamworking and networking.

The European Union's EntreComp report (2016) provides a useful framework for developing the entrepreneurship competence of its citizens, a competence that it defines as "key" for everyone in a knowledge-based economy. Entrepreneurship is described in EntreComp as a transversal skill applicable in all aspects of one's life i.e. personal development, active participation in society, (re-) entering the job market, and/or starting up a cultural/social/commercial enterprise. It defines entrepreneurship as "...*acting upon opportunities and ideas and transforming them into value ...*". Previous iterations of policy development around entrepreneurial capability had used the broader term '*having a sense of initiative and entrepreneurship*' as one of the enabler competences. The 2016 Report acknowledges that there is no universally accepted definition of entrepreneurship and EntreComp's description of entrepreneurship as a transversal skill is arguably one of its major strengths in that it can be flexed to suit a broad range of applications and circumstances. Three competence areas, namely (i) ideas & opportunities (ii) resources and (iii) into action are further distilled into 15 competences that can be used to transform ideas into action.

Beagon et al (2022) established 52 competences that should be prioritised for engineers to support the UN's 17 Sustainable Development Goals. Entrepreneurship was one of the technical competences identified as important for engineering students so they will have the necessary skills to resolve future sustainability challenges.

Methodology

Bruton et al (2023) argues that 'context' is essential, as does Miranda et al (2020), and as the context for entrepreneurship education varies across disciplines we wanted to better understand this phenomenon across disciplines at a UK university. A study was designed to explore the embeddedness of entrepreneurship in course curricula across three disciplines, namely Business and Management, Communication and Engineering. Two programmes were selected within each discipline area using a random sampling method to ensure that each programme within a discipline had an equal opportunity for selection. A document analysis approach, similar to that described by Bowen (2009), was used to systematically examine how entrepreneurship is defined, the types of entrepreneurship addressed and the teaching methods used.

The two programmes selected for analysis in the School of Engineering were the BEng Hons Biomedical Engineering and the BEng Hons Mechanical Engineering. Both programmes are of the 'thick sandwich' type which means that all students on each programme spend their third year working in industry as an integral and mandatory part of their degree programme. Successful completion of the assessments taken during the student's year in industry leads to the award of a Diploma of Professional Practice (DPP) on graduation from the honours degree. Both programmes are accredited for partial CEng status by both the Institution of Engineering and Technology (IET) and the Institution of Mechanical Engineering (IMechE) and therefore comprise of the traditional topic areas described by the Engineering Council UK, namely: Science and Mathematics; Engineering Analysis; Design and Innovation; The Engineer and Society; and Engineering Practice.

Six taught modules each of equal credit weighting (i.e. 20 credits) comprise each academic year in each programme and a total of 360 credit points are required to qualify for the award of an honours degree. The taught modules delivered in two semesters during year 1 introduce the engineering fundamentals and provide a solid year 1 foundation for year 2 learning in engineering processes and skill development. The honours year (final year) places an emphasis on the application of the engineering knowledge, skills and behaviours expected of a future Chartered Engineer.

Data selection

The document analysis approach described by Bowen (2009) was a useful starting point for the study. We were also influenced by the best practice guidelines offered by Groenland and Dana (2019) and accordingly at the outset of the study compiled a comprehensive list of texts to examine for both programmes. This list included printed and electronic documents as well as university-standard programme handbooks and individual module assessment briefs. Collaborative discussions among the research team yielded a document list of fifteen distinct documents for analysis, namely:

- Curriculum Framework (Integrated Curriculum Design Framework used across the University);
- Programme Specification/Revalidation document/Course syllabi
- Programme Handbooks (Learning Outcomes for the students taking the programme)
- Quality Assurance and Enhancement Document (Professional Engineering Institution reports, External Examiner Report, Revalidation Panel reports)
- Accreditation/Certification documents
- Module Handbooks
- Learning and Teaching Plan (module level)
- Module Content
- Assessment Briefs

A simple Master Overview Document (MOD) was developed for each degree programme as shown in Table 1. Each of the fifteen document review categories were allocated a distinct column and two additional columns provided additional space to note 'any other additional resources' and any 'general remarks' that would help answer the three main questions (as defined in Q.1 - Q.3). The modules taken in each year and semester of the degree programme were each allocated a row. The uncomplicated, straight-forward and simplistic design of the MOD was helpful as work progressed and visual patterns emerged; it was also an efficient and cost-effective data collection tool.

The RA skim-read each document, then re-read and interpreted each document as recommended by Bowen (2009) to answer the three main questions. Where evidence of entrepreneurship was taught was found in any of the selected document list, an 'X' was recorded in the corresponding cell. A separate evidence description document was created where the general remarks could be detailed and referenced, and cross-checked for accuracy by the principal investigator.

Results and discussion

MODs were compiled for each of the degree programmes selected in Business and Management, Communication and Engineering discipline areas. The findings presented in this paper relate to the two undergraduate engineering programmes only; a detailed in-depth comparative analysis will be the subject of a future publication.

Entrepreneurship definitions used

With regards to the question of "how entrepreneurship is defined" within the two engineering degree programmes, value creation and problem-solving were the two most commonly cited entrepreneurship descriptors. In the BEng Hons Biomedical Engineering programme, entrepreneurship was explicitly linked to *problem-solving in the context of design thinking* in a Design of Medical Sensors module. In the BEng Hons Mechanical Engineering programme, the emphasis was *value creation, driving innovation and problem-solving mainly within the manufacturing and/or corporate context*.

Types of Entrepreneurship mentioned

Our findings in relation to the second question of "the types of entrepreneurship mentioned" indicate a focus on certain types of entrepreneurship. Both engineering degree programmes had a significant emphasis on *Corporate Entrepreneurship* and the graduate engineer's role within larger corporate enterprises as well as *Intrapreneurship* where engineering students studied product and process improvement and problem-solving within existing organisational structures (often linked to real-life design projects from industry that engineering faculty use for scaffolding design teaching and/or assessment.)

Small Business Entrepreneurship was implicitly addressed in both degree programmes through content such as business planning and sourcing of finance, again through Design modules.

Entrepreneurship teaching methods

There were five main teaching methods used for entrepreneurship education. These are listed as: classroom instruction; collaborative learning; experiential learning; design thinking and project-based learning and are shown in Table 2.

Limitations

The document analysis revealed that the Design modules on both engineering programmes mentioned aspects of entrepreneurship multiple times whereas modules in the more numerically focussed modules such as applied science, engineering maths, engineering materials, data analysis, etc. had much fewer citations. This was not an unexpected outcome; it has however, not

yet been possible to fully triangulate the findings from the document analysis with other qualitative research methods as recommended by Yin (1994).

Table 2: Teaching methods for Entrepreneurship in the study

Teaching methods	Explanatory note
Classroom instruction	Traditional methods e.g. lectures, seminars and classroom assignments – prevalent in both degree programmes.
Collaborative learning	Team-working is emphasized e.g. the University’s graduate attribute specifically lists graduates as ‘collaborative team-worker’. Students develop their communications skills, problem-solving ability and leadership skill
Experiential learning	Both programmes are ‘thick-sandwich type’ with the third year spent in industry and additional industry site-visits are woven into modules.
Design thinking	Problem identification and the engineer’s role in creating innovative solutions are explicitly addressed
Project-based learning	A limited number of modules expose students to real-world competitive challenges where they develop and use their engineering skills to address a complex societal global problem (i.e. Engineers without Borders – UK ‘s Engineering for People Design Challenge) or a real-life corporate project for an industry partner.

Discussion

The QAA’s Subject Benchmark Statement for Engineering (2023) refers readers to earlier QAA guidance on *Enterprise and Entrepreneurship Education* (2018). The guidance aligns with the EntreComp’s description of entrepreneurship as a transversal skill that can support students to lead to “*rewarding, self-determined professional lives ... and to be able to add social, cultural and economic value to society throughout their lives*”. Creativity, innovation and design are key aspects of all engineering degrees and align well with the implicit and explicit approaches to entrepreneurship found in the course materials for the BEng Hons degrees in Biomedical and Mechanical Engineering programmes. However, examination of the MODs for both engineering programmes revealed that references to entrepreneurial skill development clustered primarily on Design modules which indicate that opportunities to embed entrepreneurial learning in the science and mathematics, and engineering analysis-type modules (i.e. the more numerical type modules) are not being optimised.

The Integrative Framework of Entrepreneurship Educational Curriculum (Cummins et al. 2021) argues for an “integrated, not inserted” approach for embedding entrepreneurship in a curriculum and we contend that scope exists within undergraduate engineering curricula to achieve such an integrated approach that should help create an entrepreneurial mind-set within engineering students. Two of the University’s graduate attributes are Collaborative Professional and Active Citizen and consequently there is an onus on all educators to seek ways within their respective modules to develop these graduate attributes in their students. This institutional priority helps focus the attention engineering educators to think more creatively about how they can include these entrepreneurial skills at module and programme level.

Concluding remarks

Entrepreneurship for undergraduate engineering students is recognised as an important area by governments, professional engineering institutions and by universities. It is a valuable employability, societal, cultural and life competence. The undergraduate engineering curricula tends to be already packed with traditional subject areas required for accreditation with entrepreneurship education primarily associated with modules in Design. Extra-curricular or co-curricular activities are very useful in providing opportunities for students to develop entrepreneurial skills but since students often self-source and select these for themselves, it's difficult to ensure that all graduating students have had sufficient exposure. Opportunities to embed entrepreneurship education implicitly and explicitly within undergraduate engineering curriculum may not be fully realised if engineering educators do not widen the pool of modules on engineering degrees *beyond Design* that develop entrepreneurial skills and competences.

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Appendix 1

Entrepreneurship Education Document Analysis Reference Template (Supplementary Material, for reference only)

(i) The Guiding Definition of Entrepreneurship

"Entrepreneurship is the process of creating value by identifying and exploiting opportunities, through the creation of new products, services, and/or business models that meet the needs of customers and/or society, while generating profits and growth for the firm and its stakeholders." (Baaken, T., & Sump, J. (2022). Entrepreneurship as a Catalyst for Sustainable Development: A Review and Research Agenda. *Sustainability*, 14(1), 200. <https://doi.org/10.3390/su14010200>)

(ii) Definitions of various types of entrepreneurship (a snapshot)

1. **Cultural Entrepreneurship:** This involves starting and running a business that promotes and celebrates cultural heritage or diversity. Cultural entrepreneurs may focus on developing products or services related to music, art, literature, or other cultural expressions.
2. **Intrapreneurship:** This involves developing entrepreneurial skills and behaviors within an existing organization or company. Intrapreneurs may work within a larger organization to develop and implement new products, services, or processes, but with the autonomy and creativity typically associated with entrepreneurship.
3. **Small Business Entrepreneurship:** This involves starting and running a small business with the goal of making a profit. Small business entrepreneurs typically focus on providing goods or services to a local market, such as a specific geographic area or industry niche.
4. **Social Entrepreneurship:** This involves starting and running a business with the goal of creating social or environmental impact, rather than just making a profit. Social entrepreneurs may focus on addressing social or environmental issues, such as poverty, inequality, or climate change, through their business ventures.
5. **Corporate Entrepreneurship:** This involves creating new businesses or innovation within an existing company or organization. Corporate entrepreneurs may work within a larger organization to develop and implement new products, services, or processes.

(iii) Teaching methods used in entrepreneurship education (a snapshot)

1. **Classroom instruction:** Entrepreneurship can be taught through classroom instruction, which may include lectures, case studies, group discussions, and assignments. Students may learn about topics such as business planning, marketing, finance, and leadership, as well as entrepreneurial mindset and skills such as creativity, problem-solving, and risk-taking.
2. **Experiential learning:** Entrepreneurship can also be taught through experiential learning, such as internships, apprenticeships, and co-op programs. These programs allow students to gain hands-on experience working with entrepreneurs and start-ups, and may provide opportunities for students to launch their own ventures.
3. **Incubators and accelerators:** Entrepreneurship can also be taught through incubators and accelerators, which provide start-ups with resources and support to help them grow and succeed. These programs may offer mentorship, coaching, access to funding, and networking opportunities, and may be affiliated with universities or private organizations.
4. **Entrepreneurship competitions:** Entrepreneurship can also be taught through entrepreneurship competitions, such as business plan competitions, pitch contests, and hackathons. These events allow students to showcase their ideas and gain feedback from investors, mentors, and other entrepreneurs, and may offer cash prizes or other incentives.
5. **Guest speakers and industry experts:** Inviting successful entrepreneurs and industry experts to speak to students can be a valuable way to teach entrepreneurship. These speakers can share their experiences and insights, provide advice and feedback, and offer inspiration and motivation.