

The Creation of Entrepreneurial Engineers: A Re-evaluation of the Standish-Kuon and Rice (2002) Typology and the Emergence of the Entrepreneurial Engineering Education (EEE) Typology

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Abstract:

Background - World economies are demanding a new type of engineer—an entrepreneurial engineer—who possesses a multidisciplinary set of technical and entrepreneurial competencies. These new engineers are essential to the fostering of entrepreneurship, innovation, and technological enhancement within an economy. Given the importance of having entrepreneurial engineers, it is necessary for tertiary-level academic institutions to prepare their engineering students to undertake these roles. This is being done by offering entrepreneurship education to engineering students.

Limited research is available as to how academic institutions structure entrepreneurship initiatives for engineering students. The Standish-Kuon and Rice (2002) study was the only available research that showed the approaches taken by the first academic institutions in the United States to educate engineering undergraduates about entrepreneurship. The findings from this study also resulted in the emergence of a typology which presented the three models to which entrepreneurship initiatives could be categorized into, and ultimately the three models that institutions could follow to educate their engineering students about entrepreneurship.

In recognition of the importance of entrepreneurial engineers coupled with the need for developing a greater understanding of entrepreneurship education for engineering students, it has become necessary to review the types of initiatives used to educate engineering students about entrepreneurship. Doing this will help to determine the relevance of the Standish-Kuon and Rice (2002) typology regarding present-day initiatives. It is important to know whether this typology still represents the initiatives offered at U.S. institutions and whether or not this typology can be applied in a non-U.S. context to show how engineering students in other countries are educated about entrepreneurship.

Purpose - The purpose of this research was to acquire information about how tertiary-level academic institutions in Australia, Canada, New Zealand, the United Kingdom, and the United States are educating engineering undergraduates about entrepreneurship. The overall objective was to determine whether the Standish-Kuon and Rice (2002) typology was still representative of entrepreneurship initiatives for engineering undergraduates, or if the typology had to be updated.

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Design/Method - This research used a desktop review approach conducted in two phases. In the first phase, the data was collected from entrepreneurship initiative descriptions on the websites of tertiary-level academic institutions in the United States. In the second phase, the data was collected from entrepreneurship initiative descriptions on the websites of institutions in Australia, Canada, New Zealand, and the United Kingdom. A content analysis was conducted, and the distinguishing criteria identified in the Standish-Kuon and Rice (2002) typology were used to categorize the entrepreneurship initiatives reviewed.

Findings - The findings showed that a total of five models were used to categorize entrepreneurship initiatives for engineering undergraduates. This demonstrates that academic institutions in the five countries use one (or in some cases more) of the five models to educate engineering undergraduates about entrepreneurship. The presence of the five models showed that the Standish-Kuon and Rice (2002) typology required updating to reflect present-day initiatives for engineering undergraduates. These findings, as a result, laid the foundation for the emergence of a new typology, which was subsequently entitled the Entrepreneurial Engineering Education, or EEE, typology.

Conclusion - The Standish-Kuon and Rice (2002) typology, while still valuable, requires updates to represent the evolving educational needs of the engineering field and entrepreneurship education's place in engineering. The need for extension has resulted in a new typology, the EEE typology, which could ultimately be used to conduct future research that will enhance the field of entrepreneurial engineering and gain insight into entrepreneurial engineering education. Areas of interest for future research are also discussed.

1. Introduction

World economies are demanding a new type of engineer. These engineers must not only be capable of enabling technological advancement, but also of fostering the occurrence of entrepreneurship and innovation. This is because opportunities and challenges emerge in these economies which require engineers to develop new, innovative technologies that serve to solve global problems and enhance the overall quality of life; essentially these new engineers must invent the future (Byers et al., 2013).

Traditionally, engineering education has focused on the acquisition of “left-brain” skills—technical and analytical skills that enable an individual to think logically (Pistrui et al., 2011). However, the roles of engineers have expanded due to “non-traditional” engineering work, the creation of knowledge-based economies, an increased use of technology in engineering education and practice, and an increased emphasis on entrepreneurship (Sunthonkanokpong, 2011). Because today’s engineers need to go beyond just inventing new products, they need to have a variety of non-technical skills in addition to technical knowledge and competency (Abdulwahed et al., 2013). They need to be capable of understanding the forces that govern the market, commercializing and advocating for the use of new technologies, and recognizing and taking advantages of opportunities (Duval-Couetil et al., 2010). Consequently, a purely technical degree is no longer sufficient to adequately prepare engineers for the future that lies ahead (Arciszewski, 2014; Byers et al. 2013). Engineers also need to acquire a combination of practical, analytical, and inventive knowledge and skills that enable them to address the present and future challenges faced by society. In other words, engineers need to be entrepreneurial.

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Incorporating entrepreneurship education into the engineering curriculum provides students not only with experience in launching new ventures or start-ups, but also with experience in areas such as product design and development, prototyping, and market analysis (Nelson & Byers, 2015). Skills such as these are valuable to both start-ups as well as existing companies (Byers et al. 2013). The integration of entrepreneurship into aspects of engineering has consequently given rise to a phenomenon that is referred to as Entrepreneurial Engineering or Engineering Entrepreneurship.

Various definitions of Entrepreneurial Engineering exist. Lumsdaine and Binks (2003) defined it as the combination of entrepreneurship skills, technical knowledge, and an understanding of basic business skills, such as marketing and finance, creativity, strategic thinking, and innovation. Polczynski and Jaskolski (2005, p. 95) described entrepreneurial engineering as requiring the “integration of strong technical capabilities with the ability to advance new business opportunities...” In other words they viewed it as a process that incorporates (a) the skills and knowledge needed for successful entrepreneurship, (b) a focus on the ability to recognize, assess and exploit technology-based opportunities, and (c) learning about how to deal with identifying, acquiring, developing, and transferring technology into new products and services. Elia et al. (2011, p. 152) most recently defined this phenomenon as the “development and transfer of technology into commercially viable products and services with sustainable competitive advantage in the global marketplace.” Being an entrepreneurial engineer requires the individual to strive to solve the unmet needs of the end-customer, by using technology and focusing on the benefits of products over design features (Kriewall & Mekemson 2010). However, it also allows for the combination of technical knowledge with basic business skills leading to the ability to be creative and innovative, and to think strategically (Lumsdaine & Binks 2003).

Entrepreneurship education has been found to shape the attitudes and skills necessary for entrepreneurship and innovation to occur (Wilson 2004). The integration of entrepreneurship into technology and science curricula has been promoted due to these departments being considered breeding grounds for innovative ideas and new companies (Wilson 2008). Entrepreneurship has also been linked to economic growth and the overall development of society, which therefore requires engineering graduates to possess an entrepreneurial mindset (Mäkimurto-Koivumaa et al., 2013). Incorporating entrepreneurship into the engineering curriculum has provided students with the ability to identify customer needs and market niches; develop new, revolutionary ideas; take innovative approaches; and possibly create a new business (Lumsdaine & Binks 2003). The integration of entrepreneurship and innovation into a curriculum can also develop an entrepreneurial mindset; and the attitudes, behaviors, capabilities, and drive that students need to possess in order to create a more entrepreneurial and innovative society (Wilson 2008). Researchers have also found that entrepreneurship education has positively increased attitudes towards entrepreneurship (Pihie & Bagheri 2010; Robinson et al., 1991; Shinnar et al., 2009), self-efficacy levels (Duval-Couetil et al. 2010; Pihie & Bagheri 2010), and entrepreneurial intentions (Keat et al., 2011; Naktiyok et al., 2010), all of which have resulted in students either following or considering the pursuit of an entrepreneurial career path. In the case of new venture creation, entrepreneurship education has built the knowledge base needed to launch and manage new ventures (Menziez & Paradi 2003; Schaper & Casimir 2007), and has been linked to the increased number of potential start-ups (Menziez & Paradi 2003; Tung 2011). Teaching entrepreneurship to engineering students also has the benefit of exposing students to the professional roles played by engineers as well as the skills to develop products specifically targeted to meet the needs of consumers (Nichols & Armstrong 2003).

To develop entrepreneurial attributes within engineering students, as well as overcome the limitations of the traditional engineering curricula, tertiary-level academic institutions are increasingly incorporating entrepreneurship education into their engineering courses (Polczynski & Jaskolski 2005). These institutions have developed entrepreneurship initiatives that offer various forms of

educational options aimed at fostering entrepreneurial knowledge and competencies within engineering students. The educational options offered include, for example, online learning courses (Byers et al. 2013), workshops (Byers et al. 2013), extra-curricular programs (Byers et al. 2013), case studies (Weaver & Rayess 2010), elective programs such as formal certificates and minors (Byers et al. 2013; Duval-Couetil et al., 2013), entrepreneurship programs and experiences (Byers et al. 2013), and capstone courses where students get the opportunity to engage in activities such as developing a feasibility plan for a product, or developing a spin-off business unit (Dabbagh & Menascé 2006). The academic institutions first introduce engineering students to entrepreneurship at the undergraduate level, which is a time when engineering students are believed to require entrepreneurial knowledge and attributes (Arciszewski 2014; National Academy of Engineering 2004). Introducing entrepreneurship to engineering students during their undergraduate education allows the students to learn about entrepreneurship during the developmental years of engineering education (Polczynski & Jaskolski 2005). Despite this, there is little empirical evidence which identifies the combination of options that are available for selection to academic institutions and shows how these institutions have structured their entrepreneurship initiatives.

An extensive search of the literature has revealed that there is only one study that has examined this issue. This study was undertaken by Standish-Kuon and Rice (2002), who developed a typology of models based on data collected in 1997 from a small sample of U.S. tertiary-level academic institutions that had introduced entrepreneurship initiatives for their engineering students. However, as the engineering field has evolved, so have the educational approaches that have been used to develop entrepreneurial engineers. It is therefore necessary to revisit the Standish-Kuon and Rice (2002) typology to determine if it is representative of present-day entrepreneurship initiatives.

This paper focuses on the models that are presently being used by tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship. Subsequently, it determines the applicability of the Standish-Kuon and Rice (2002) typology for representing entrepreneurship initiatives for engineering undergraduates that are offered today.

2. The Standish-Kuon and Rice (2002) Typology for Creating Entrepreneurial Engineers

Given the need to educate entrepreneurial engineers, and the lack of entrepreneurial research specific to the engineering discipline, Standish-Kuon and Rice (2002) set out to examine how engineering—as well as science—students were being introduced to the notion of entrepreneurship. To do this, they explored technologically oriented entrepreneurship initiatives: i.e. initiatives that focused on areas such as entrepreneurship principles, patents, prototyping, commercialization, and legal issues. The aim of the Standish-Kuon and Rice (2002) research was to identify how and why entrepreneurship was taught to engineering and science students.

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Table 1. The Standish-Kuon and Rice (2002) Typology for introducing entrepreneurship to engineering and science students Adapted from Standish-Kuon and Rice (2002)

Characteristics	Model A <i>Business School</i> model	Model B <i>Engineering School</i> model	Model C <i>Multi-School</i> model
The schools responsible for the development of the entrepreneurship initiative	The initiative is developed by the business school	The initiative is developed by the engineering school through a cross-pollination between the engineering and business schools (i.e. a sharing of knowledge and ideas)	This is a partnership involving the business school, the engineering school, and one or more technical schools.
The home base of the entrepreneurship initiative	The initiative is housed in the business school	The initiative is housed in the engineering school	The initiative is housed in either the business school or the engineering school which tilts the balance toward the particular school
The curriculum and its development	The technological curriculum is developed by the business school in collaboration with the engineering school	The technological curriculum is developed by the engineering school and exists alongside the curriculum offered by the business school	The technological curriculum is formed through the collaboration of the business school, the engineering school, and the other technical schools involved
Target students	Business, engineering, and possibly other non-business students	Engineering students	Students from each school in the partnership
Where the courses are taught	The business school but entrepreneurship faculty from the business school can also teach entrepreneurship courses in the engineering school	The engineering school but the business school can also reserve a number of spaces in its entrepreneurship courses for non-business students	The business school or the engineering school; each entrepreneurship course will recruit a certain percentage of engineering students

Using a multiple case study research design, Standish-Kuon and Rice (2002) looked at the entrepreneurship initiatives offered at six U.S. tertiary-level academic institutions (Carnegie Mellon University, Rensselaer Polytechnic Institute, Stanford University, the University of California, Los Angeles, the University of Colorado at Boulder, and the University of Iowa). The data for this study was collected in 1997, as a part of the founding of the National Consortium of Entrepreneurship

Centers. The institutions included in the study were selected using convenience sampling based on three criteria: they were geographically diverse, they had a reputation for engineering and the sciences, and each one had a center or program for entrepreneurship. Standish-Kuon and Rice (2002) used a longitudinal study over one year, where they collected data using various qualitative techniques including site visits, in-person interviews, telephone interviews, analysis of internal documents, and finally a follow-up survey.

A number of findings emerged from this study. First, the researchers found that the common primary goal of the entrepreneurship initiatives was the teaching of entrepreneurship, particularly at the undergraduate level. The findings revealed other goals including the development of curricula, the creation of new ventures, economic development, and the retention of faculty. However, the main finding to emerge from the Standish-Kuon and Rice (2002) study was the identification that the initiatives offered at the institutions examined followed approaches or models which differed mainly based on the location of entrepreneurship initiatives within the university. Standish-Kuon and Rice (2002) found that the approach taken by the institutions studied was influenced by a number of contextual factors, including who championed the development of technological entrepreneurship initiatives and the assets available to support the initiative (for example, the availability of qualified faculty). The findings revealed that the initiatives offered at the six institutions studied followed one of three approaches/models: the Business School model (Model A); the Engineering School model (Model B); and the Multi-School model (Model C). A summary of these three models is presented in Table 1.

As shown in Table 1, each of the three models was compared based on five criteria: 1) the schools that were responsible for the development of the initiative, 2) the home base of the initiative, 3) the curriculum, 4) the target students, and 5) the location where the entrepreneurship courses were taught. The information regarding the location of the entrepreneurship courses also provided insight into the faculty used to teach the entrepreneurship courses.

3. Revisiting the Standish-Kuon and Rice (2002) Typology for Creating Entrepreneurial Engineers

Standish-Kuon and Rice's (2002) seminal work provides an important and valuable foundation for understanding the types and range of educational approaches used to teach entrepreneurship in engineering schools. However, as acknowledged by the researchers, these educational approaches do evolve. In fact, by the completion of their study, two of the institutions examined were appearing to evolve from one model to another, due to changes in the key leadership positions within the university and the availability of faculty members who could teach entrepreneurship. Since Standish-Kuon and Rice's (2002) initial study, several factors have led to changes occurring in engineering education; which, in turn, have caused institutions to re-evaluate and develop educational initiatives in the area of entrepreneurship.

Changes have occurred in entrepreneurship education itself. Research has shown a growth in entrepreneurship educational offerings offered at tertiary-level academic institutions (Fretschner & Weber 2013; Kuratko 2005; Morris et al., 2014). Entrepreneurship education has moved outside of the business school, with students in a variety of disciplines being educated about entrepreneurship. Research has shown the presence of entrepreneurship education in areas such as agriculture (Mehlhorn et al., 2015; Zampetakis et al., 2013) physics (Arion 2013), and engineering and science (Byers et al. 2013; Shartrand et al., 2010). In engineering, for example, entrepreneurship is one of the fastest growing academic areas with an increasing number of engineering students being educated about entrepreneurship (Besterfield-Sacre et al., 2013; Duval-Couetil et al. 2010; Duval-Couetil et al., 2011). In fact, despite entrepreneurship education being first seen in business schools, there is evidence that

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the presence of entrepreneurship in schools such as agriculture, engineering, and arts and sciences exists with minimum or no involvement from the business school (Katz 2003). Research has shown that external stakeholders and networks are playing greater roles in contributing to and influencing the combination of entrepreneurship and engineering (Byers et al. 2013; Kriewall & Mekemson 2010). External stakeholders are in fact considered essential players in the creation of an entrepreneurship ecosystem (Isenberg 2011). There has also been an increase in entrepreneurship educational offerings leading to “university-wide” entrepreneurship education, where entrepreneurship education has become a vital component of the institution and its culture, allowing the institution to become more innovative, risk-taking, and proactive (Morris et al. 2014).

Table 2. Examples of previous research into entrepreneurship education and entrepreneurship education for engineering and other non-business students outside the United States.

Researchers	Country	Purpose of Research
Abdulwahed, Abu Hamad, Hasanain and Hasna (2013)	Qatar	<ul style="list-style-type: none"> • Presentation of literature on entrepreneurship and engineering entrepreneurship education. • Proposal for embedding entrepreneurship in engineering education at Qatar University.
Antonites and Nonyane-Mathebula (2012)	South Africa	<ul style="list-style-type: none"> • Developing an understanding entrepreneurial orientation (EO) of engineers.
Lumsdaine and Binks (2003)	United Kingdom	<ul style="list-style-type: none"> • Presentation of experiences in teaching entrepreneurship to engineering undergraduates.
Papayannakis, Kastelli, Damigos and Mavrotas (2008)	Greece	<ul style="list-style-type: none"> • The introduction of entrepreneurship education in the engineering curriculum.
Rahman, Ghani, Ismail and Zain (2012)	Malaysia	<ul style="list-style-type: none"> • Identification of interest among engineering students towards entrepreneurship.
Solymosy and Gross (2015)	Canada	<ul style="list-style-type: none"> • Gravitation of engineers toward entrepreneurial opportunities.
Souitaris, Zerbinati and Al-Laham (2007)	United Kingdom and France	<ul style="list-style-type: none"> • Exploration of the effect of entrepreneurship programs on the entrepreneurial attitudes and intentions of science and engineering students.
Sundar and Madhavan (2013)	India	<ul style="list-style-type: none"> • Examination of the entrepreneurial propensity among engineering students.
Verzat and Bachelet (2006)	France	<ul style="list-style-type: none"> • Investigating the educational factors that led to the development of an entrepreneurial spirit among engineering college students.

In the specific case of the engineering discipline, engineering schools are increasingly including entrepreneurship programs and courses; in fact, this inclusion is possibly one of the fastest growing areas curricula-wise (Duval-Couetil et al. 2011). Standish-Kuon and Rice’s (2002) study identified the educational approaches or models initially developed by tertiary-level academic institutions to create entrepreneurial engineers. However, given the evolution that has occurred in world economies and engineering education, it is necessary to determine firstly, if this typology is still applicable today, and secondly, whether or not this typology needs to be updated to reflect today’s engineering educational

curriculum. Consequently, this research sought to investigate whether the Standish-Kuon and Rice (2002) typology is still representative of entrepreneurship initiatives for engineering students today by exploring the range of approaches used by tertiary-level academic institutions in the United States to introduce entrepreneurship principles to engineering students.

Furthermore, despite the presence of research into entrepreneurship education for engineering students in countries besides the United States, there is no documented evidence that shows studies similar to the Standish-Kuon and Rice (2002) study being performed outside the United States. Examples of these studies are presented in Table 2.

As a result, this research additionally sought to determine whether this typology could be applied in a non-U.S. context.

4. Method

4.1 Research Design

As previously explained, the purpose of this research was two-fold: to determine whether the Standish-Kuon and Rice (2002) typology was representative of present-day entrepreneurship initiatives for engineering students offered at U.S. tertiary-level academic institutions, and whether the typology that represents U.S.-based entrepreneurship initiative could be applied to entrepreneurship initiatives for engineering students outside the United States. As a result, the decision was made to use a qualitative approach executed in two phases. The first phase investigated the initiatives offered by institutions in the United States and the results from this phase were used in the second phase to investigate the initiatives offered by institutions outside the United States. To acquire the necessary data, a desktop review was conducted of descriptions of entrepreneurship initiatives for engineering students that were available on institution websites.

4.2. Population and Context

The research was carried out over a period of three months and examined entrepreneurship initiatives for engineering students in the United States, as well as Australia, Canada, New Zealand, and the United Kingdom. Due to the short period that was allowed for the collection of data, a decision was made to focus on countries where the primary language of instruction at the institution was English. The United States was included due to the fact that initiatives offered by institutions in this country formed the basis of the Standish-Kuon and Rice (2002) study. It was also the most entrepreneurial country based on the Global Entrepreneurship Index list (Acs et al., 2016). In addition, the Accreditation Board for Engineering and Technology, Inc. (ABET), the board that accredits post-secondary education programs offered by U.S. institutions in the areas of applied science, computing, engineering, and engineering technology, reformed its accreditation criteria to better align the skills taught to engineering students to the needs of industry (Prados et al., 2001). This change, referred to as ABET's Engineering Criteria 2000 (EC2000), resulted in a greater emphasis placed upon the development of the skills needed to succeed in the modern-day engineering arena, and a more extensive range of job options, highlighted in ABET's Criterion 3 (Shuman et al., 2005). The skills in this new criteria consists of a combination of technical or "hard" skills and non-technical/professional or "soft" skills (Shuman et al. 2005). These new skills are also aligned with the skills and abilities that can be obtained from entrepreneurship education, including the addressing of real-world problems, the identification and pursuit of opportunities, interacting and working on multi-disciplinary teams, the abilities to communicate effectively and lead others, persevering in the face of adversity and failure, the handling of risks, and the ability to be flexible when faced with uncertainty (Duval-Couetil et al., 2015).

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Australia, Canada, and the United Kingdom were also included due to the fact that these countries, in addition to the United States, were the most entrepreneurial English-speaking countries, ranking second, third, and ninth on the current Global Entrepreneurship Index list (Acs et al. 2016). Like ABET, a review of the accreditation criteria of the main accreditation boards in the three countries - Engineers Australia, Engineers Canada, and Engineering Council U.K. - showed that a combination of “hard” and “soft” skills was also identified as being necessary for engineering students. New Zealand was also included in the research due to its close proximity and relationship with Australia and the Asia-Pacific region. A review of the accreditation criteria from the Institution of Professional Engineers New Zealand (IPENZ) also revealed a combination of “hard” and “soft” skills like those of the previous four countries.

The decision was made to focus on entrepreneurship initiatives that were offered to engineering undergraduates, given the importance of engineering undergraduates being introduced to entrepreneurship in the formative years of their engineering education. Unlike the Standish-Kuon and Rice (2002) study, which examined technologically-oriented entrepreneurship initiatives, this research examined all types of initiatives where engineering students could learn about entrepreneurship. From these initiatives, information centered around the main criteria used for distinguishing amongst the models that were identified in the Standish-Kuon and Rice (2002) study (i.e., the schools responsible for the development of the initiatives and the home base of the initiatives) were acquired from the initiative descriptions on institution websites.

A total of 600 institutions from the five countries were initially selected for possible inclusion in this research. These institutions offered engineering programs accredited by Engineers Australia, Engineers Canada, IPENZ, Engineering Council U.K., and ABET at the undergraduate level. In Phase 1 of the study, 414 institutions in the United States accredited by ABET were reviewed. The websites of these institutions were then reviewed for instances of entrepreneurship initiatives that were open to engineering undergraduates. This review resulted in the 414 institutions being reduced to a total of 203, all of which were included in this research. In the second phase of the research, the population examined included the institutions that offered undergraduate engineering programs accredited by Engineers Australia, Engineers Canada, Institution of Professional Engineers New Zealand (IPENZ), and the Engineering Council U.K. This consisted of 186 institutions: 36 Australian institutions, 42 Canadian institutions, 8 New Zealand institutions, and 100 U.K. institutions. The process of locating entrepreneurship initiatives on institution websites was also applied in the second phase. This resulted in a further 78 institutions being included. Therefore, of the 600 institutions examined, a total of 281 institutions, equivalent to 47%, offered entrepreneurship initiatives to engineering undergraduates, and as a result comprised the research population.

The data collected from the U.S. institutions was reviewed against distinguishing criteria of the Standish-Kuon and Rice (2002) typology. The typology was then applied to the data collected from the Australian, Canadian, New Zealand, and U.K. institutions to determine the suitability of the typology for representation of non-U.S. initiatives.

4.3. Data Collection

The data for this research was collected in two phases. In both phases, using the desktop review approach, the initiative descriptions were reviewed specifically to collect two pieces of information. First, the descriptions were reviewed for information pertaining to which schools were involved in the development of the initiatives. This information was typically present either in the introductory paragraphs of the initiative descriptions, or in some case, the first page that was present which contained links to subsequent pages.

Second, a review of the descriptions was done to acquire information about where the initiative was housed. To obtain this information, the websites of the individual schools at the institution (typically the engineering or business schools) were reviewed in order to determine the school (or schools) that housed the initiative. In other cases, the information was collected either by visiting the links to initiative descriptions that were situated on the webpages of the engineering school listing the educational options that were available to students, or by visiting the webpages that listed all educational options offered at the institution.

The information about this specific criteria, presented in the Standish-Kuon and Rice (2002) study, was collected due to the fact that these criteria are the main types used to identify the model that an initiative followed.

4.4. Data Analysis

The data was analyzed using a content analysis method. For the entrepreneurship initiatives based in the United States, each entrepreneurship initiative description on the institutions' websites was reviewed and information was collected about the schools responsible for the development of the initiative and the home base of the initiative. The initiatives were then categorized according to the criteria that distinguished the models in the Standish-Kuon and Rice (2002) study. Notes were made about any information that partially deviated from the descriptions provided by Standish-Kuon and Rice (2002). If an initiative did not fit or resemble the model descriptions from the Standish-Kuon and Rice (2002) typology, it was placed in an "Other" category and analyzed inductively. Based on the information collected, decisions were made regarding the applicability of the Standish-Kuon and Rice (2002) typology. The same approach was taken for initiatives for engineering undergraduates that existed outside the United States, with the distinguishing criteria identified in the Standish-Kuon and Rice (2002) being used as a measure to review each initiative. Three rounds of checking were conducted in order to confirm that each initiative was associated with the correct model.

5. Findings

5.1. Phase 1 Findings: The United States

5.1.1. Finding 1: The Standish-Kuon and Rice (2002) models still hold... but with some differences.

The findings based on data collected from the U.S. institutions has shown that the findings obtained from the original Standish-Kuon and Rice (2002) study, although still present, has indeed evolved. As a reminder, Table 3 shows the characteristics that were sought in this research project.

The findings confirmed the presence of the three models initially identified by Standish-Kuon and Rice (2002). In comparison, however, differences were found in the distinguishing characteristics of these three models. In the Standish-Kuon and Rice (2002) study, the findings showed that the business school alone developed the initiative without the involvement of other schools. In contrast, although the findings showed the presence of entrepreneurship initiatives created solely by the business schools, there were instances of initiatives that were developed by the business school in collaboration with other schools; primarily the engineering school. The findings also revealed that the Business School model initiatives, as identified in the Standish-Kuon and Rice (2002) study, were housed in the business school.

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Table 3. The characteristics used to distinguish amongst models in the Standish-Kuon and Rice (2002) study

Model	The schools responsible for the creation and development of the entrepreneurship initiative	The schools where the initiative was housed (i.e., the home base of the entrepreneurship initiative)
<i>The Business School model</i>	The business school	The business school
<i>The Engineering School model</i>	The engineering and business schools	The engineering school
<i>The Multi-School model</i>	The business school, the engineering school, and one or more technical schools	The business school or the engineering school

For the Engineering School model, the findings revealed that there were entrepreneurship initiatives created by the engineering school in collaboration with the business school, as identified in the Standish-Kuon and Rice (2002) study. However, the findings also revealed the presence of Engineering School model entrepreneurship initiatives created solely by the engineering school. Like the Standish-Kuon and Rice (2002) study, the initiatives were found to be housed in the engineering school. In contrast to the findings of the Standish-Kuon and Rice (2002) study, the findings also showed that there were Engineering School model entrepreneurship initiatives housed in other locations, including the business school, both the engineering school and an innovation center, freestanding entrepreneurship schools, and across an institution, as was the case for engineering-only institutions.

Standish-Kuon and Rice (2002) classified Multi-School model entrepreneurship initiatives as those developed by the business school, the engineering school, and one or more science or technical schools. Although the findings from this research showed evidence of initiatives developed by the engineering, business, and science/technical schools, the findings also revealed that there were Multi-School model partnerships involving the business and engineering schools as well as other schools at the institution. These schools included, for example, the arts school, the law school, or the journalism school. An exception was seen in the case of one institution explored, where a partnership existed that included multiple schools but excluded the business school. Standish-Kuon and Rice (2002) also determined that Multi-School model entrepreneurship initiatives were housed either in the business school or engineering school. This research found that Multi-School model entrepreneurship initiatives were primarily housed in the business school with a few initiatives housed in the engineering school. However other home-base locations were identified, including the School of Arts & Sciences and freestanding entrepreneurship schools. Some initiatives were housed in both the engineering school and other locations such as the School of Arts & Sciences, the School of Visual & Performing Arts, or the School of Business. The data analysis also showed that there were Multi-School model entrepreneurship initiatives housed equally in each of the member schools of the partnership.

5.1.2. Finding 2: Two new models were identified

Based on similar characteristics, the analysis of the remaining initiatives that did not fit the distinguishing characteristics of the Business School, Engineering School, and Multi-School model entrepreneurship initiatives were categorized into two groups, ultimately resulting in two additional models—consequently, these models were aptly named the External Partnership model and the Institution model.

The External Partnership model shared similarities with the Engineering School model. However, the difference was that the development of External Partnership model entrepreneurship initiatives stemmed from a collaborative effort between the home institution and external partners. These partnerships generally involved the engineering school of the institution and either external networks that supported the development of entrepreneurship education, local organizations that contributed resources to entrepreneurship initiatives, or other tertiary-level academic institutions. In addition, some partnerships also involved the business school of the home institution. The engineering school was the primary home base of External Partnership model entrepreneurship initiatives, however the findings also showed that some initiatives were housed in either the business school, or both the engineering and business schools.

The Institution model, on the other hand, contained entrepreneurship initiatives derived from efforts by the institution to educate the entire student body about entrepreneurship, regardless of the degree and major being pursued. These initiatives were generally developed from the activities of a freestanding entrepreneurship school or the collective actions of the schools of an institution. The findings also revealed that Institution model entrepreneurship initiatives were primarily housed in freestanding entrepreneurship schools. Other initiatives were housed, for example, in the business school, the engineering school, both the business and engineering schools, or the architecture school. There was evidence showing Institution model entrepreneurship initiatives being housed in both freestanding entrepreneurship schools and an additional school, such as the business or engineering schools.

5.1.3. Finding 3: U.S. institutions either offered single or multiple entrepreneurship initiatives, which determined the number of models used.

As stated in the Methodology section, a total of 203 U.S. institutions from the population examined offered entrepreneurship initiatives to engineering undergraduates. The findings showed that in some cases, institutions offered only one initiative that their students could participate in; in other cases, the institutions offered multiple initiatives. This ultimately determined the number of models used by institutions. Details of this are presented in Table 4.

Table 4: Breakdown of the entrepreneurship initiatives for engineering undergraduates offered and number of models used by U.S. academic institutions [N = 203]

Number of models used by institutions	A single entrepreneurship initiative or multiple entrepreneurship initiatives?	Number of institutions	Percentage (%) of institutions
1	Single entrepreneurship initiative	123	61
1	Multiple entrepreneurship initiatives	38	19
2	Multiple entrepreneurship initiatives	39	19
3	Multiple entrepreneurship initiatives	3	1

As shown in Table 4, the majority of the U.S. institutions developed one initiative for engineering undergraduates. The table also shows that it was more common for these institutions to use one model for educating engineering undergraduates about entrepreneurship.

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5.1.4. Finding 4: The Business School model was the model most commonly used by U.S. institutions.

The findings showed that amongst the five models found in U.S. institutions, the Business School model was the most popular. This is shown in Table 5, which takes into account the fact that some institutions used multiple models to educate engineering undergraduates about entrepreneurship.

Table 5: Breakdown of the models used in U.S. tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship [N = 203]

Model	Number of institutions following the model	Percentage (%) of institutions following the model
<i>Business School</i>	126	62%
<i>Engineering School</i>	61	30%
<i>Multi-School</i>	16	8%
<i>External Partnership Institution</i>	25	12%
	20	10%

The results shown in Table 5 confirm that the Business School model is the most commonly used model. The number of institutions using this model was more than twice the number that used the second most common model, the Engineering School model. The findings also revealed that one of the original models identified by Standish-Kuon and Rice (2002), the Multi-School model, was the least used of the five models, with the model used by less than 10% of the U.S. institutions reviewed.

5.1.5. Finding 5: The data from the U.S. institutions have laid the foundation for a new typology—The Entrepreneurial Engineering Education (EEE) Typology.

The original typology developed by Standish-Kuon and Rice (2002) identified three models used by U.S. institutions to educate engineering undergraduates about entrepreneurship. However, given the increase in entrepreneurship education offerings, the findings have revealed that institutions now use five models to educate engineering undergraduates. As a consequence of this, the findings have resulted in the emergence of a new typology, aptly named the Entrepreneurial Engineering Education, or EEE, typology. Table 6 presents a summary of the models that form the EEE typology.

5.2. Phase 2 Findings: Australia, Canada, New Zealand, and the United Kingdom

The Entrepreneurial Engineering Education (EEE) typology that emerged from the Phase 1 findings was used to review the entrepreneurship initiatives for engineering undergraduates that were offered by tertiary-level academic institutions in Australia, Canada, New Zealand, and the United Kingdom. The following findings emerged from this phase of the research.

5.2.1. Finding 6: The EEE typology is useful for the description of entrepreneurship initiatives for engineering undergraduates in Australia, Canada, New Zealand, and the United Kingdom.

As noted in the first phase of this research, the data collected from entrepreneurship initiatives offered at U.S. academic institutions used one of five models to educate engineering undergraduates about entrepreneurship. The findings from the second phase of this research showed that the EEE typology can be used to determine the models used by institutions in Australia, Canada, New Zealand, and the United Kingdom. Details of this are presented in Table 7.

Table 6. The models used to educate engineering undergraduates about entrepreneurship

Model	Model name	Distinguishing Characteristic of Model
Model 1	The <i>Business School</i> model	<i>Entrepreneurship initiatives developed either solely by the business school or by the business school in collaboration with another school—primarily the engineering school—with the initiatives housed in the business school</i>
Model 2	The <i>Engineering School</i> model	<i>Entrepreneurship initiatives developed either solely by the engineering school, or by the engineering school in collaboration with the business school, with the initiatives primarily housed in the engineering school</i>
Model 3	The <i>Multi-School</i> model	<i>Entrepreneurship initiatives resulting from a partnership involving the engineering school, the business school, and one or more of the other schools at the academic institution, with some partnerships excluding the business school</i>
Model 4	The <i>External Partnership</i> model	<i>Entrepreneurship initiatives developed from a partnership involving either the engineering school or both the engineering and business schools of an institution and external organizations or other tertiary-level academic institutions</i>
Model 5	The <i>Institution</i> model	<i>Entrepreneurship initiatives developed by academic institutions to educate all students at an academic institution, regardless of major, about entrepreneurship</i>

Table 7: The models used to educate engineering undergraduates about entrepreneurship in Australia, Canada, New Zealand, and the United Kingdom (√ - yes; × - no)

Country	<i>Business School</i> model	<i>Engineering School</i> model	<i>Multi-School</i> model	<i>External Partnership</i> model	<i>Institution</i> model	Total number of models
Australia	√	√	×	×	√	3
Canada	√	√	×	√	×	3
New Zealand	√	√	×	×	×	2
United Kingdom	×	√	×	×	√	2

First, as shown in Table 7, the findings showed that no further models were identified in the data collected from the initiatives in the four additional countries. As a result, the models in the EEE typology were sufficient for determining the types of entrepreneurship initiatives offered by institutions.

In addition, Table 7 shows that only one model was used in the four countries: the Engineering School model. This was a significant finding given that findings from Shartrand et al. (2010) indicated that it was less likely to find entrepreneurship education programs for engineering undergraduates housed in engineering schools. The Business School model was present in three of the four countries, the only exception being the U.K. The Institution model was used in two countries—Australia and the United Kingdom—while the External Partnership model was only seen in Canada. The Multi-School model was not present in any of the countries outside the United States.

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5.2.2. Finding 7: The Engineering School model is the model most commonly used by tertiary-level academic institutions in Australia.

In Australia, as previously noted, three models were used by academic institutions: the Engineering School, the Business School, and the Institution models. The Phase 2 findings revealed that eight of the thirteen Australian institutions that had entrepreneurship initiatives for engineering undergraduates offered single initiatives, thereby following one model. Three institutions offered multiple initiatives all under the same model. Two institutions offered multiple initiatives, categorized under different models. This meant that the two institutions followed multiple models. Table 8 shows a breakdown of the models used in this country.

Table 8: Breakdown of the models used in Australian tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship ($N = 13$)

Model	Number of institutions following the model	Percentage (%) of institutions following the model
<i>Business School</i>	3	23%
<i>Engineering School</i>	10	77%
<i>Institution</i>	2	15%

As explained in the Phase 1 findings, the Business School model was the one that was commonly used in the United States. In contrast, as shown in Table 8, the findings from Phase 2 showed that the Engineering School model was the most common in Australia, used by more than 75% of the institutions.

5.2.3. Finding 8: The Engineering School model is the model most commonly used by tertiary-level academic institutions in Canada

Like the Australian institutions, the findings revealed that three models were used by Canadian institutions. These three models included the Business School, the Engineering School, and the External Partnership models. Of the 24 Canadian institutions that educated engineering undergraduates to be entrepreneurial, 17 offered single entrepreneurship initiatives, which meant that each institution followed a single model. The remaining seven institutions offered multiple initiatives; three institutions offered multiple initiatives under a single model while the remaining four institutions offered multiple initiatives and subsequently followed two models. The breakdown of the models used by Canadian institutions is presented below in Table 9.

Table 9: Breakdown of the models used in Canadian tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship ($N = 24$)

Model	Number of institutions following the model	Percentage (%) of institutions following the model
<i>Business School</i>	11	46%
<i>Engineering School</i>	16	67%
<i>External Partnership</i>	1	4%

As shown in Table 9, the Engineering School model is the model that was most commonly seen in more than 60% of the Canadian institutions. The findings also showed that the remaining institutions used the Business School model, with only one institution additionally using the External Partnership model.

5.2.4. Finding 9: The Engineering School model is the model most commonly used by tertiary-level academic institutions in Canada

The five New Zealand institutions with entrepreneurship initiatives for engineering undergraduates used one of two models: the Business School model and the Engineering School model. The breakdown showing how these models are used is shown in Table 10.

Table 10: Breakdown of the models used in New Zealand tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship ($N = 5$)

Model	Number of institutions following the model	Percentage (%) of institutions following the model
<i>Business School</i>	1	20%
<i>Engineering School</i>	4	80%

As shown in Table 10, four of the five institutions used the Engineering School model. This showed that, as in Australia and Canada, the Engineering School model was the model most commonly used in New Zealand. Furthermore, only one of these five, an institution using the Engineering School model, had multiple initiatives, both under the same model. The findings also revealed that unlike the Australian and Canadian institutions, none of the New Zealand institutions used multiple models.

5.2.5. Finding 10: The Engineering School model is the model most commonly used by tertiary-level academic institutions in the United Kingdom.

As in the case of the New Zealand institutions, U.K. institutions were found to use either one of two models: the Engineering School model and the Institution model. Table 11 shows a breakdown of the models as used by U.K.-based institutions.

Table 11: Breakdown of the models used in U.K. tertiary-level academic institutions to educate engineering undergraduates about entrepreneurship ($N = 36$)

Model	Number of institutions following the model	Percentage (%) of institutions following the model
<i>Engineering School</i>	33	92%
<i>Institution</i>	3	8%

As shown in Table 11, the Engineering School model is the model predominantly used by U.K. institutions. The findings also showed that, as in New Zealand, none of the thirty-six institutions that had entrepreneurship initiatives for engineering undergraduates used multiple models. However, six institutions, all of which used the Engineering School model, offered multiple initiatives that used the same model.

6. Conclusion

In conclusion, this research focused on the examination of the approaches to entrepreneurship education in the engineering field and the applicability of the Standish-Kuon and Rice (2002) typology of models to present-day entrepreneurship initiatives for engineering undergraduates both within and outside the United States. The findings from this research showed that the Standish-Kuon and Rice (2002) typology contributed valuable insight into the ways in which institutions are educating engineering undergraduates about entrepreneurship. Taking into consideration the demand for entrepreneurial engineers and the increase in entrepreneurship education offered to engineering students, a review of the Standish-Kuon and Rice (2002) typology became necessary given that the data the typology was based on was collected in 1997 from a small sample of U.S.-based institutions. The findings from the review have suggested that the information from the Standish-Kuon and Rice (2002) typology has evolved; this revelation ultimately laying the foundation for a new typology. This typology, which was named the Entrepreneurial Engineering Education (EEE) typology, consists of five models – the three models originally identified by Standish-Kuon and Rice (2002) (i.e. the Business School, Engineering School, and Multi-School models), and two new models (i.e. the External Partnership and Institution models).

From the Standish-Kuon and Rice (2002) study, it was recognized that the schools responsible for the development of the entrepreneurship initiatives as well as the location within which the initiatives were housed were both needed to determine which model an entrepreneurship initiative followed, and ultimately which model an institution used. These criteria were used in this research to identify the models used. However, the findings have showed that the schools responsible for the development of the entrepreneurship initiatives became the main criterion used to categorize the initiatives. This was due to the fact that although initiatives followed the same model, they were not necessarily housed in the same locations. Evidence of this was seen in several of the EEE typology models. Despite this, there were instances where the location of the initiative was essential. This was particular in the case where initiatives were developed by both the business and engineering schools. If an initiative that was developed by the business and engineering schools was housed in the business school, it was identified as a Business School model initiative. Likewise, those housed in the engineering school were identified as an Engineering School model initiative.

The findings provided insight into the models that were most commonly used in all five countries. They showed that the Business School model was the model used by the majority of U.S. academic institutions that offered entrepreneurship initiatives for engineering undergraduates. However, outside the United States, the findings showed that institutions mainly used the Engineering School model in educating their engineering undergraduates about entrepreneurship.

The emergence of the EEE typology has important implications for both theory and practice. The major implication for theory is that the findings of this study have laid the foundation for the creation of a more developed and detailed typology of the models that are used to develop entrepreneurial attributes in engineering students. This aligns itself with the growth that has occurred in this area since Standish-Kuon and Rice (2002) conducted their study. This extended typology proposes possibilities to paint an overview of entrepreneurial engineering education and allows the opportunity to generate a greater understanding of how academic institutions are addressing the need for entrepreneurial engineers in world societies.

For practice, the major implications inform university educators and administrators, providing greater insight into the range of models being used by tertiary-level academic institutions to teach undergraduate engineering students about entrepreneurship. Additionally, academic institutions are using new and different approaches to educating engineering students about entrepreneurship. This

was evidenced by the use of the two new models, and the offering of multiple initiatives which provide students with the opportunities to choose how they would like to learn about entrepreneurship. The presence of these new models suggests that academic institutions, both in and outside the United States, are continuing to develop and try new educational innovation modules in this space. The findings from the research confirm that the inclusion of entrepreneurship into the engineering undergraduate curriculum has become more common and widespread. As a result, institutions may need to dedicate more attention to how their entrepreneurial initiatives are differentiated from those offered at other institutions if they are to remain competitive and attract potential students in the future.

This research has provided possibilities for future research. The findings, as previously explained, have laid the foundation for the development of the EEE typology. First, to learn more about this new typology, the remaining characteristics identified in the Standish-Kuon and Rice (2002) study can be examined in order to determine if and how these characteristics have changed. Furthermore, additional characteristics can be researched so as to gain a more detailed idea of how these models exist.

Second, it is important to explore the learning outcomes achieved by engineering students who participate in entrepreneurship initiatives—more specifically, whether the model that is used affects student outcomes. This involves comparing and contrasting the educational outcomes of schools following each model in order to determine if the model used produces different outcomes for students. In addition, research can be done into the effectiveness of these models by comparing students' performance, i.e., achievement and demonstration of entrepreneurial knowledge and skills. Third, elements of the EEE typology can be used to investigate entrepreneurship education in other disciplines, academic levels, and countries. It can, for example, be used to examine how engineering postgraduate students learn about entrepreneurship. In addition, it can be used to investigate how institutions educate students, both undergraduates and postgraduates, in other disciplines about entrepreneurship. This could potentially be used to formulate typologies that are representative of these other disciplines and university education levels. Furthermore, since this research focused on entrepreneurship initiatives for engineering undergraduates in Australia, Canada, New Zealand, the United Kingdom, and the United States, it can be used as a means of investigating entrepreneurship initiatives offered to engineering students in other countries. This could either result in the generalization of the EEE typology or the extension of the EEE typology to reflect the activities that occur in other countries.

Finally, this research used a desktop review of initiative descriptions on institution websites. To obtain relevant information, additional methods could be employed in future studies. Such studies could be carried out using, for example, observational studies, focus groups, surveys, or interviews done with educators or administrators of engineering programs in order to explore, in more detail, how entrepreneurship initiatives are delivered.

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