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Educating Engineers: A Postgraduate Entrepreneurship and Innovation Perspective*

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The aim of this paper is to clarify the educational methods that effectively educate and develop engineers in entrepreneurship in specific postgraduate programs. The purpose is to provide a framework by which entrepreneurship educators may develop and implement programs that are unique to engineers and postgraduate entrepreneurship education programs. The paper integrates two prominent frameworks and a strand of recent literature on entrepreneurship education to develop a conceptual model for engineers in a postgraduate entrepreneurship education setting. Findings include unique theoretical and applied initiatives in all dimensions of postgraduate entrepreneurship education programs, including the addition of a new dimension: community and outreach. The result is a conceptual framework, highlighting components and initiatives within the context of ontology, learning, audience, objectives, outcomes, assessment, content, pedagogy, community and outreach. The predominant theoretical implication is the need to consider entrepreneurship education in a postgraduate context targeted at engineers. We add to the body of knowledge by identifying education insights unique to this context. Limitations include applicability to the contextual scenario provided. The main practical implications concern program developers, educators, teachers and trainers in postgraduate entrepreneurship education for engineers. The paper sheds new light on the design and implementation of such programs. A conceptual framework is proposed for postgraduate entrepreneurship and engineering education, adding to the body of knowledge in scant literature in this domain. Dimensions of entrepreneurship education programs are demystified within the context provided.

Keywords: engineering education; entrepreneurship education; postgraduate entrepreneurship education programs

1. Introduction

In a global, knowledge-driven economy, technological innovation and entrepreneurship—the transformation of knowledge into products, processes, services and commercialization—are critical to competitiveness, long-term productivity growth, and the generation of wealth [1]. Commercialization is at the intersection of innovation and entrepreneurship,comprising the processes and activities that bridge the gap between economic value creation and economic value realization. Preeminence in technological innovation and entrepreneurship requires leadership in all aspects of engineering research to make a bridge between scientific discovery and practical applications, engineering education to give engineers and technologists the skills to create and exploit knowledge and technological innovations, and the engineering profession and practice to translate knowledge into innovative, entrepreneurial, competitive products and services [2]. This paper addresses the gap between the pure sciences (engineering) and commercialization (entrepreneurship) by applying innovative, transparent, and reproducible procedure [3]. Our premise is that Engineers complete Bachelors degrees in Engineering, and then often undertake business Postgraduate courses, such as MBAs. We, however, advocate the content of such business courses, providing substance and relevance to include substantial entrepreneurship and innovation content.

Entrepreneurship is about heterogeneity—entrepreneurs create their ventures from all kinds of backgrounds, with a variety of business ideas, and with a variety of ways in which to create such ventures [4, 5]. So too is the heterogeneity of entrepreneurship education, ranging across variances in dimensions of contextualization, outcomes, objectives, assessment, content, audience, learning, and pedagogy [1]. Much has been written on such heterogeneity in entrepreneurship education, yet it is sparse in the field of educating engineers in dedicated postgraduate entrepreneurship courses [6]. We refer to dedicated postgraduate entrepreneurship courses as professional Masters' coursework degrees, dedicated entirely to entrepreneurship education, in contrast to traditional higher degree programs in management, notably MBA programs, which have not focused on the philosophy, activities and skills required for the develop-

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ment of a new enterprise, the growth of entrepreneurial ventures, and the development of high growth ventures, and commercialization of innovation by engineers. By entrepreneurs we refer to individuals who currently actively participate in entrepreneurship activities and [7], in contrast to aspiring, novice and nascent entrepreneurs. Many engineering studies have explored the role and importance of graduate entrepreneurship, particularly regarding entrepreneurial intentions. The depth of literature has, however, predominantly ignored entrepreneurship education for qualified engineers and, in particular, those engaging in entrepreneurship-specific higher education postgraduate programs. An example of such a program is the internationally awarded Master of Entrepreneurship and Innovation, developed and hosted by the Australian Graduate School of Entrepreneurship (AGSE). We explicitly exclude MBAs, even those with streams or subjects in entrepreneurship, as these programs have not been designed specifically for entrepreneurship and innovation. We concur with the work of Maritz et al. [8] that entrepreneurship as a discipline is primarily focused on opportunities (as in entrepreneurship-specific programs), whereas leadership and management (as in MBAs and management programs) are primarily focused on the management of resources.

Our premise is that entrepreneurship education varies significantly between actively engaged engineers and nascent entrepreneurs [4] as is the variation between dedicated entrepreneurship postgraduate programs and generic postgraduate programs. In essence, such contextualization proposes a learning process and program application that is unique to such contextualization [9]. The literature describes entrepreneurs according to their ability to adapt to the changing demands of their stakeholders and their own business environment, and the ability to offer a constant process of innovation to communities [7]. There is also evidence that academically educated entrepreneurs are more important in developing regional economies than entrepreneurs with a lower level of education; hence the importance of enhancing entrepreneurship education directed for experienced engineers [9]. This is certainly no different to executive MBA programs directed at senior executives and leaders in business although it is in a leadership and/or management context. We thus highlight the importance of postgraduate education programs targeted at engineers [10].

This paper aims to clarify the educational methods that effectively develop engineers in entrepreneurship specific postgraduate programs. The purpose is to provide a framework by which entrepreneurship educators may develop and implement programs that are unique to engineers and postgraduate education programs. The paper begins with a literature review of engineering education (contextual); then entrepreneurship education and programs [4], adding to the longitudinal significance of two prominent frameworks [11, 1]. Fayolle and Gailly [11] placed emphasis on entrepreneurship teaching models and learning processes, whereas the Maritz and Brown [1] paper placed emphasis on components of entrepreneurship education programs (EEPs). The former predominantly provides a framework for discussion on entrepreneurs (learning specific), and the latter on components of postgraduate education programs. We by no means propose these two approaches as polar opposites, rather as integrative and complimentary processes. To enhance conceptualization, we then provide an example of an award-winning entrepreneurship education program targeted at engineers in the postgraduate education domain. By so doing, we fill a gap in the literature on engineering and entrepreneurship education for active engineers engaging in entrepreneurship specific postgraduate education. We conceptualize within postgraduate coursework programs and an engineering context, although the example provides a research nexus.

2. Engineering education

The American Accreditation Board for Engineering and Technology (ABET) sets the following objectives for engineering degree programs: ''Students should gain an ability to apply knowledge of mathematics, science, and engineering to design and conduct experiments as well as to analyze and interpret data, to function multidisciplinary teams and to communicate effectively.'' In a study of inadequate diversity of engineering education, Duderstadt [2] found that the qualities missing included an engineering student's inability to communicate well, a lack of commitment to lifelong learning, an inability to adapt to an increasingly diverse world, an inability to drive change, and an inability to commercialize their technological innovations. Bordogna [12] identified that beyond a strong foundation in fundamentals, such as science, mathematics, and engineering sciences, engineers require broader skills such as systems integration (synthesis), problem solving, the ability to realize products, the facility to enhance creative opportunity with intelligent technology, the ability to manage complexity and uncertainty, teamwork, the ability to advocate and influence, entrepreneurship and knowledge integration, and education and mentoring. In a study by Shartrand and Weilerstein [13], it was found that traditional engineering capstone courses typically neglect to incorporate

appropriate entrepreneurship content. This results in engineering graduates being unable to commercialize their innovations after graduation. In an article by Byers et al. [14], it was found that engineering students engaging in entrepreneurship courses 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.

We now conceptualize entrepreneurship and innovation education within an engineering context.

3. Teaching models

Fayolle and Gailly [11] developed their widely accepted teaching model framework for entrepreneurship education, integrating a number of dimensions related to ontological and educational levels. We discuss these dimensions across the two identified levels. They further identified propositions, based upon their theoretical underpinnings. These propositions will be discussed and expanded upon, within our defined context in this paper.

3.1 Ontological level

The authors propose two dimensions: an explicit definition and acknowledgement of what entrepreneurship is (and is not) as a teaching field and a definition of what "education" implies for educators and for students within the entrepreneurship context.

Taking the cognizance of a widely accepted definition of entrepreneurship, we refine the distinction between various schools of thought. As such, Shane [7] defines entrepreneurship as "an activity that involves the discovery, evaluation, and exploitation of opportunities to introduce new goods and services; ways of organizing, markets, process, and raw materials through organizing efforts that previously had not existed". Taking that entrepreneurship is the examination of how, by whom, and with what effects, opportunities to create goods and services are discovered, evaluated and exploited, then entrepreneurship education could be defined as "knowledge transfer regarding how, by whom, and with what effects, opportunities to create future goods and services are discovered, evaluated and exploited". Fayolle and Gailly[11] lead with the following proposition:

> Each entrepreneurship education program should be based on a clear conception of entrepreneurship leading to a non-ambiguous definition of entrepreneurship education.

Following on from an accepted definition of entrepreneurship education, Fayolle and Gailly [11] postulated that teaching and educating have different meanings and do not necessarily meet with the same objectives. They identified teaching as the imparting of knowledge or skill to condition to a certain action [9] or frame of mind; and education as the development of the innate capabilities to stimulate, refine or develop mental or moral growth [4]. As such, the authors postulate that both notions of teaching and education should be combined in entrepreneurship programs. When it comes to professionalism in delivering entrepreneurship education, the educator and/or teacher should adopt a particular philosophic orientation. Such philosophy offers goals, values and attitudes to strive for; it can thus be motivational and inspirational. This leads to Fayolle and Gailly's [11] second proposition:

> The educator or teacher should clarify for each entrepreneurship training course, where he or she is in charge, his or her philosophical positions concerning key conceptions about teaching, the role of teacher and the role of students or participants.

3.2 Educational level

Within this level, heterogeneity of entrepreneurship education is emphasized. Design and the architecture of education programs are developed around five specific interrelated questions, in the following order [11]:

1. Why (objectives, goals)?
2. For whom (targets, audiences)?
3. For which results (evaluations, assessments)?
4. What (contents, theories)?
5. How (methods, pedagogies)?

We discuss these five questions in more detail in the next section of the literature review, whereby we elaborate on the development of entrepreneurship education programs (EEPs). We also provide a brief overview and propositions developed by Fayolle and Gailly [11]in this regard:

The objectives and goals of entrepreneurship education should be connected to learning and social needs.

> (Why): Entrepreneurship education courses should target clear any comprehensive objectives at the micro (individual participant) level and at the macro (organization, society) level.

The variety of audiences of entrepreneurship education programs includes students with various socio-demographic characteristics and various levels of involvement and aspirations in the entrepreneurial process.

> (For whom): Entrepreneurship education courses should be designed through a thorough under-

standing of the profile and background of the audience, particularly in terms of prior exposure.

Evaluation is a key dimension of the framework, dependent upon the effect of time and contextual variables.

(For which results): In line with the objectives and the audience characteristics, the identification of the relevant evaluation criteria, mainly at the learning level of Kirkpatrick's approach, and their effective measurement methods should be defined for each entrepreneurship education course.

Levels of learning involve three main dimensions, which orient and structure the contents of entrepreneurship education: the professional dimension, the spiritual dimension and the theoretical dimension. The professional dimension relates more specifically to practical knowledge (know-how); the spiritual dimension to individuals positioning themselves in space and time as regards the entrepreneurial phenomenon (know-why and know-when), and the theoretical dimension to the theories and scientific knowledge in order to understand entrepreneurial phenomenon.

(What): Depending on the objectives and audience profile, the contents of each entrepreneurship course should be explicitly defined through a combination of three dimensions (professional, spiritual and theoretical).

A wide range of pedagogical methods, approaches and modalities have been tested and used in entrepreneurship education; and pedagogy is a means to achieve objectives.

(How): The selection of the pedagogical methods for each entrepreneurship education course should rely upon their adequacy and an priori efficiency regarding the objectives, the audience characteristics, the contents and the constraints due to the institutional context.

In the following section, Fayolle and Gailly [11] identify approaches to develop specific learning processes in entrepreneurship education.

4. Learning processes

Learning is a cognitive process of acquiring and structuring knowledge, which includes making meaning from existing knowledge and experience, and generating new solutions [11]. Learning in entrepreneurship includes tacit and explicit knowledge, and generating new solutions and solving complex problems involves a strong interaction of such knowledge. Fayolle and Gailly [11]developed entrepreneurship learning into three categories:

1. Learning to become an enterprising individual;
2. Learning to become an entrepreneur; and
3. Learning to become an academic.

Learning to become an enterprising individual involves entrepreneurship as a broad concept, focusing on the spiritual dimension, the expected changes in attitudes and intention toward entrepreneurship, the large diversity of audience and the high importance of entrepreneurs as role models in the classroom. Relevant concepts and theories include entrepreneurial intentions, theory of planned behavior and entrepreneurial orientation. Learning to become an entrepreneur involves entrepreneurship as a specific concept, a professional dimension, learning by shaping pedagogies, expected acquisition of skills and practical knowledge, expected development of entrepreneurial competencies and audience consisting of would be entrepreneurs. Relevant concepts and theories include entrepreneurial process theories, emergence, learning from failure bounded rationality, effectuation, entrepreneurial cognition and entrepreneurial management and growth. Learning to become an academic involves the academic conception of entrepreneurship, a focus on the theoretical dimension, the didactical education model, research issues and expected acquisition of theoretical and scientific knowledge. Relevant concepts and theories include entrepreneurship as a research domain and theories to teach and do research in the field.

Of particular interest to the current research is that Fayolle and Gailly [11] excluded learning for a prominent audience, that of current entrepreneurs and individuals partaking in entrepreneurial activities and ventures [10]. Within this context, we include engineers wishing to commercialize their innovations. To include this important sector, we include literature more specific to this audience [14]. Entrepreneurship requires numerous skills that are difficult to define as individual atomic subjects, with the heart of entrepreneurial competence within psychological and social skills [Rae 2008]. An effective learning environment for entrepreneurial skills falls under the pragmatic philosophy of pedagogy. Entrepreneurship education should focus on developing creativity, critical thinking and reflection among individuals, influencing the ability to develop entrepreneurial knowledge.This point of view is shared by Sawyer [15], who believes teaching for the innovation economy must be improvisional, whereby students may co-construct their own knowledge. He believes that students should not only consume knowledge, but also rather produce new knowledge. He argues that creative collaboration in classrooms align with the social nature of

entrepreneurship and innovation. This aligns closely with the limitations found in engineering education [2].

Fayolle and Gailly's research [11] identifies the need to reconsider entrepreneurship education in its wide diversity, both from an ontological and a pedagogical point of view. Hence, we introduce engineering [16] as an additional learning process, bridging a gap in the entrepreneurship and engineering education literature. The next section incorporates the development of entrepreneurship education programs [1].

5. Entrepreneurship education programs

We compliment and integrate the work of Fayolle and Gailly [11] with the more recent research on the EEPs of Maritz and Brown [1]. This research resonates well with the original teaching model and framework for entrepreneurship education as developed by Fayolle and Gailly [11]. We define EEPs as any pedagogical program or process of entrepreneurship education for knowledge transfer regarding how, by whom, and with what effects, opportunities to create future goods and services are discovered, evaluated and exploited [11].

Maritz and Brown [1] developed a comprehensive framework through which entrepreneurship education might be evaluated and developed. They identified how the components of EEPs are most effectively integrated. We provide an overview of the components and relationships of EEPs, as identified by Maritz and Brown [1]:

1. Context
2. Outcomes
3. Objectives
4. Audience
5. Content
6. Pedagogy
7. Assessment.

Context is the condition and circumstances that are not only relevant to the framework, but contribute to its full meaning. Prior to specifying program objectives, contextualization of EEPs is necessary. Such contextualization is as widespread as the heterogeneity of programs [5], and may include the context in education setting [4], proximity [6] philosophy; graduate level; international gender, competitive offerings enterprise culture, outcomes; audience, student and educator diversity, skills, knowledge and attitudes; types of entrepreneurship teaching methods and pedagogy and evaluation [1, 5, 6, 10].

The terms outcomes and objectives are most often integrated in entrepreneurship education programs [1]. We, however, identify these as separate components in EEPs. Objectives refer to the EEP goals, broadly described as pedagogical, social and/or economic [11]. Outcomes, on the other hand, refer to the actions and activities of participants after intervention in EEPs. The entrepreneurship education literature predominantly identifies outcomes with regard to the following competencies and activities: skills, knowledge, attitudes, graduate careers, self-efficacy, intentionality, competitiveness and practical learning [9]. Specifying objectives can be seen as one of the first steps in EEPs, and an accurate understanding of the objectives leads to improved design and evaluation of the program [5]. The objectives component resonates with the "Why" dimension of the Fayolle and Gailly [11] model.

The heterogeneity of the audience (program participants and other stakeholders) is crucial because of their different learning needs, the diversity of the stakeholders, and the student and educator diversity. This component resonates with the "For whom" dimension of the Fayolle and Gailly [11] model. This is particularly relevant to engineers, since they have a distinct scientific and mathematical skills bases.

The content of EEPs is likely the area of most extensive variation, taking cognizance of audience, theory and practice, context, purpose, diversity, type and pedagogy [1, 5, 9, 12]. Entrepreneurship courses that are solely practical or solely theoretical would be ruined, and thus should not be mutually exclusive. A comprehensive study by Mwasalwiba [17] identified the most common subjects and contents of entrepreneurship courses: resources marshaling and finance (16%), marketing and salesmanship (14%), idea generation and opportunity discovery (13%), business planning (12%), organization and teambuilding (10%), new venture creation (9%) and SME management (8%). Other subjects ranking lower (in order) included: risk and rationality, legal issues, management of innovation and technology, franchising, family businesses, negotiation skills, communication skills and problem solving. Content is directly related to types of programs. Kirby [18] reviewed about 205 EEPs and found that they have three main focuses:

1. programs that are for giving an orientation and awareness about entrepreneurship;
2. programs that develop competencies for new enterprise formation, self-employment, or economic self-sufficiency; and
3. programs that focus on small business survival and growth.

Content resonates with the "What" dimension of the Fayolle and Gaillymodel. Of particular significance to engineers is point 2.

Pedagogical methods have been identified as the decisive factors of success for entrepreneurship education in the twenty-first century and pedagogy should be seen as a means to achieve the objectives of EEPs, and not as an end in themselves. Pedagogy is influenced by contextualization, level: such as undergraduate and postgraduate, expectations and outcomes, prior experience; practice-based and experiential, innovation, entrepreneur type and setting. Maritz and Brown [1] and Fayolle and Gailly [11] further identify traditional and non-traditional methods, proposing integration, in that one method does not necessarily fit all. Others, however, postulate that despite the particular pedagogy, student engagement remains essential in EEPs. Pedagogical methods include, but are not limited to assigned readings, lectures, case studies, exams, individual and/or group work, creativity and innovation, handouts, videos, workshops and seminars, interviews with entrepreneurs, role playing, mentors, competitions, guest speakers, e-learning and online learning, simulation, blended learning and engagement. In a comprehensive study on methods, Mwasalwiba [17] identified twenty-six commonly used pedagogies. In order of importance, the most used included: lectures, case studies, group discussion, business simulation, role models or guest speakers, business plan creation and project works. Pedagogy and methods resonates with the ''How'' dimension of the Fayolle and Gailly model.

Assessment is a complex issue in EEPs, and despite the importance of design and the individual components of an EEP, assessment continues to be a much under-researched area, and a significant area for future research. Assessment of EEPs refers to the overall measurement and effectiveness of EEPs; whereas assessment of student learning refers to methods of evaluating individual student competencies and understanding of content by way of assessment items such as assignments. The assessment of EEPs is driven by program objectives, content and pedagogies. Due to the practice-based and experiential nature of entrepreneurship education, individual assessment should be a combination of theory and practice measurement. Assessment resonates well with the ''For which results'' dimension of the Fayolle and Gailly model.

The complexity of EEPs can be seen by the variety of options for each major component (for example, case studies as a form of pedagogy) and how each major component relates to the other. We identify contextualization as the driving force regarding the cohesion and integration of components. Such integration includes the entrepreneurship education purpose model of Morris (2010), identifying components important to the purpose of EEPs. These include the transformation of students, the transformation of the university and programs, and the effect of community engagement. Community outreach is often not prioritized by institutions delivering EEPs, with the most common outreach activities including: business centers and clubs with local entrepreneurs, technical and management assistance to entrepreneurs, incubation services, public symposia and student consulting projects [17]. Another integration element, currently scant in the entrepreneurship education literature, is interdisciplinary or cross-disciplinary entrepreneurship education. This may either include the natural home or faculty for entrepreneurship education, and the delivery of entrepreneurship across disciplines or faculties.

Since EEPs are not homogeneous, greater detail of EEPs is necessary to understand the impact of the components of such programs. In the following section, we provide a brief example of an award winning EEP [10] providing contextualization of an EEP in postgraduate higher education targeted at practicing entrepreneurs.

6. Entrepreneurship education in practice

The Master of Entrepreneurship and Innovation (MEI) is a postgraduate Masters by coursework degree offered by the Australian Graduate School of Entrepreneurship (AGSE) at Swinburne University of Technology, Hawthorn, Victoria, Australia (MEI 2013). The MEI program is a leading, internationally awarded and accredited entrepreneurship Masters by coursework degree program, and has been recognized as the leading entrepreneurship postgraduate by coursework program in the Southern Hemisphere, ranking in the top five in the world. The program was a finalist in the 2010 United States of America Small Business and Entrepreneurship (USASBE) Global Entrepreneurship Education Awards [10].

Initially, the program started in 1986 as a Graduate Diploma in Entrepreneurship Studies and commenced in a Masters format in 1989, as an initiative in the Faculty of Engineering at Swinburne University of Technology, developing engineering students' commercial awareness, business aptitude and the capacity to convert ideas into successful innovations. The primary aim of the original program to seek a commitment to the notion of ''theory for practice sake'' remains today. Through a myriad of re-accreditation processes over the years, the MEI program currently consists of core entrepreneurship specific content, pedagogy and subjects. The development and integration of these subjects is based upon clearly defined student learning goals, objectives and outcomes. These goals are further integrated across

assessing new ventures and opportunities, planning and managing rapid growth, integrating interdisciplinary approaches and applying innovative solutions. Core elements of the program design involve a flexible admission process, team teaching and progressive credentialing. Flexible admission is achieved through varying entry standards to attract students who have demonstrated entrepreneurial ability or intent. Team teaching involves academics with practical and relevant experience, often referred to as "pracademics". This combination provides a rich and unique learning environment for students. Progressive credentials allowed for multiple exit points, placing emphasis on outcomes rather than the procuring of qualifications.

With over 200 active students enrolled in the program, over 1000 MEI graduates have been responsible for launching successful new high growth ventures, enhancing prosperity and well-being in society and the community at large [16]. Research over the years has identified that in excess of 92% of students completing the program launch new ventures [10]. This is not surprising as the program targets entrepreneurs in practice (including engineers). This excludes the expansion of the MEI into the Israeli market, contributing an additional 200 students in 2003, 2004 and 2005. The program articulates its ongoing international reputation in entrepreneurship education, currently integrating with the Global Innovation Management (GIM) initiative, a European Union Erasmus Mundus funded program, involving Strathclyde University, Aalborg University, Hamburg University of Technology, and the Australian Graduate School of Entrepreneurship (GIM 2013).

Traditional higher degree programs in management, notably MBA programs, have not focused primarily on the philosophy, activities and skills required for the development of new enterprises, the growth of small and medium size companies, and development of high growth ventures. This program in Entrepreneurship and Innovation is designed to substantially improve the probability of success of an entrepreneur involved in a new venture creation, innovation projects inside existing organizations, or commercialization projects involving new inventions or new knowledge. Graduates from the program are active in starting new businesses, advising entrepreneurs and meeting the educational and policy-making needs of our community.

The program has its roots in theory and practice, and has been through various re-accreditation stages over the years. New initiatives and program realignment is the result of energized program facilitators, extensive community engagement, academic rigor and consultative processes. International best practice and benchmarking has been a characteristic of the program, lending on the expertise of collaborative partners, institutions and academics throughout the globe. A nexus to research was the launch of the inaugural Entrepreneurship Research Exchange (ERE) Conference 10 years ago, based upon the core values and principles of the Babson ERE.

The most recent re-accreditation of the MEI program (to commence in 2014) includes a dynamic integration of subjects and content. This has been specifically developed to incorporate cross-disciplinary: cross-faculty and, in particular, engineering related integration. Exit credentials exist, whereby students may exit with a graduate certificate in entrepreneurship and innovation. This provides a basic and fundamental understanding and application of commercialization principles. Subjects in this suite consist of Opportunity Discovery, Creativity and Innovation, Finance for Entrepreneurs and Strategic and Entrepreneurial Marketing. More advanced subjects include Opportunity Development, Entrepreneur's Toolkit, Product Innovation, Global Entrepreneurship and Innovation, Corporate Entrepreneurship and Innovation, and Contemporary Challenges in Entrepreneurship and Innovation. These subjects were specifically designed to accommodate and develop the non-technical skills (science and mathematics) of engineers; whilst taking cognizance of the shortcomings of traditional engineering education courses [2, 4,14].

Program aims, learning goals, objectives, learning and teaching approaches, implementation and evaluation, graduate attributes and teaching approaches are discussed in the next section.

7. Discussion

Whilst the teaching model framework of Fayolle and Gailly [11] and the EEP design of Maritz and Brown [1] provide comprehensive frameworks, they neglected to specifically address EEPs for engineers in entrepreneurship specific postgraduate education settings. Whilst much of their work integrates with this audience; context, content, outcomes, objectives, pedagogy and community engagement in particular require additional and unique insights. We provide appropriate and significant insight into these dimensions, providing such insights in the form of a conceptual framework, represented in Fig. 1.

7.1 Ontology and learning

From an ontological perspective, we apply the widely accepted definition of entrepreneurship of Shane [7] and subsequent Shane (2012). We, how-

ever, include a definition of the entrepreneur, in order to place emphasis on the context of engineering and technology entrepreneurs [16] in this paper: *A person who habitually creates and innovates to build something of value around perceived opportunities*. Emphasis is placed on the term *habitual,* highlighting the importance of education for engineers in this context. We adapt the definition of entrepreneurship education to include a distinct postgraduate contextualization for this research: *knowledge transfer in a postgraduate by coursework context regarding how, by whom, and with what effects, opportunities to create value are discovered, evaluated and exploited.* From a teaching philosophical perspective, we adopt the notion of integrating teaching and education,

Together with a philosophical orientation of pragmatism, being *theory for practice*. Our application resonates well with the propositions of the Fayolle and Gailly [11] teaching model:

> Each entrepreneurship education program should be based on a clear conception of entrepreneurship leading to a non-ambiguous definition of entrepreneurship education. Educator or teacher should clarify for each entrepreneurship training course he or she is in charge of his or her philosophical positions concerning key conceptions about teaching, the role of teacher and the role of students or participants.

From a learning process perspective, we expand upon the learning categories identified by Fayolle and Gailly [11]. Their categories included learning to become an enterprising individual or entrepreneur, and learning to become an academic. We include the notion within the context of engineers, hence, *learning to become a competent entrepreneur*, by commercializing engineering innovations. Adding to the body of knowledge developed by Fayolle and Gailly [11], we provide key dimensions of the teaching model in this context as: entrepreneurship as a niche and specific concept, focus on practice application, learning by doing pedagogies, learning independence by andragogy and heutagogy, expected changes in behavior as accomplished engineers and entrepreneurs expected development of entrepreneurial, creative and innovative competencies, main audience consisting of engineers and practicing entrepreneurs in a postgraduate context. Relevant concept and theories to include application of theoretical concepts, effectuation lean start-up, design thinking), action learning, innovation and creativity and product and technology development. These resonate well to fill the gap in educating engineers.Our learning philosophy to include andragogy and heutagogy, a more independent and self-directed learner, whereby we focus on learner-focused education, complements our pedagogical initiatives. We deem this appropriate due to the proposed concepts and theories as depicted above. In addition, we concur with the research of Sawyer [15], whereby students not only absorb and consume new knowledge, but also co-construct their own new knowledge. We thus focus on developing creativity, critical thinking, reflection and development of new entrepreneurial knowledge, factors as identified by Dudestadt [2] as deficiencies in engineering graduates. This is depicted in the new subject and content matter of the MEI development (2014).

From an educational and EEP perspective, we temporarily dismiss the heterogeneity of entrepreneurship education within our current context. This is due to contextualization within postgraduate entrepreneurship education for practicing entrepreneurs and engineers. Integrating the work of engineering education, we demarcate dimensions as represented in Fig. 1.

7.2 Context and audience

Narrowing heterogeneity of EEPs, we provide primary contextualization within an education setting dimension. Such contextualization refers to postgraduate entrepreneurship education by coursework programs and, more specifically, to those courses specializing in engineering and entrepreneurship only. As such, generic MBAs are excluded, as they do not specifically offer entrepreneurship as the primary outcome (albeit offering electives and majors). An example of an entrepreneurship 'only' course is provided in the previous section. We further conceptualize by targeting engineers involved in entrepreneurial ventures and activities, together with distinct skills, knowledge and attitudes. We include all stakeholders in our identification of audience, taking cognizance of diversity of stakeholders. Stakeholders, however, also form an integral component of the community and outreach dimension of the framework. An example of such is integration in the use of advisory panels on engineering and entrepreneurship education programs, most often representing prominent community networks and individuals. Institutional stakeholders also play an important role and, in this context, the transformative approach to entrepreneurship education on an interdisciplinary platform is developed. This may include entrepreneurship education across faculties, for example, engineering, design, social sciences and business. Furthermore, institutional and internal stakeholders hold significant power and process, particularly regarding accreditation and regulatory issues. Such contextualization to the audience dimension resonates with the Fayolle and Gailly teaching model: *(For*

whom), Entrepreneurship education courses should be designed through a thorough understanding of the profile and background of the audience, particularly in terms of prior exposure.

7.3 Objectives, outcomes and assessment

Such programs aim to educate and develop engineers, providing them with the specialist skills needed to lead and manage the process of innovation, business start-ups, high growth and rapid change [2, 12–14]. Learning goals and objectives include assessing new ventures and opportunities, planning and managing rapid growth, integrating interdisciplinary approaches and applying innovative solutions. Outcomes include student entrepreneurial competencies and skills, including the capability in chosen professional areas (engineering in this case), entrepreneurial behavior and skills, the ability to operate effectively and ethically, to be adaptable and manage change and be aware of environments. Mwasalwiba [17] identified the extensive literature available on EEP outcome measurement, most often centered on entrepreneurial intentionality. We exclude such measurement in this context, as we are already dealing with experienced engineers and entrepreneurs (hence intentionality is not applicable within context). Assessment is primarily a combination of theory and practice measurement, involving simulation, presentations and assignment based assessment. These dimensions resonate well with propositions of the Fayolle and Gailly teaching model:

> (Why): Entrepreneurship education courses should target clear and comprehensive objectives at the micro (individual participant) level and at the macro (organization, society) level.
>
> (For which results): In line with the objectives and the audience characteristics, the identification of the relevant evaluation criteria, mainly at the learning level of the Kirkpatrick's approach, and their effective measurement methods should be defined for each entrepreneurship education course.

7.4 Content and pedagogy

We identify these dimensions as the most dynamic, in that technological advancements, innovation and environmental changes have results in ongoing challenges to content and the delivery thereof. These dimensions further integrate with other dimensions of EEPs, and are co-dependent on each other. For example, content and delivery thereof is specifically designed to deliver on learning outcomes and initiatives, such as pedagogy, andragogy and heuragogy. Content includes (but are not limited to): design thinking, lean start-up, creativity and innovation, opportunity evaluation, technology and product development, marketing, finance, entrepreneurship types (such as corporate, social, technological), research, managing growth, business models and plans. Pedagogical initiatives include an integration of learning dynamics (blended, online, practice-based, problem based, transmission models, action, experiential, interdisciplinary, linear and heuristic), lectures, case studies, group integration, simulation, role models, projects, presentations, and business plan creation. An overall objective of content and pedagogy includes student engagement, as well as the dimensions of learning. These dimensions resonate well with the Fayolle and Gailly proposition on methods and pedagogies:

> (How): The selection of the pedagogical methods for each entrepreneurship education course should rely upon their adequacy and a priori efficiency regarding the objectives, the audience characteristics, the contents and the constraints due to the institutional context.
>
> (What): Depending on the objectives and audience profile, the contents of each entrepreneurship course should be explicitly defined through a combination of three dimensions (professional, spiritual and theoretical).

7.5 Community and outreach

This dimension differentiates institutional proactivity and transformative links with the communities they serve and, most often, is an indicator of the effectiveness and success of EEPs. A community engagement or outreach dimension is usually excluded from EEP literature, but we believe an inclusive approach places importance of this activity on overall EEP effectiveness and outcomes. Our application is a transformative approach to entrepreneurship education: three pillars including the effect on students (entrepreneurial competencies), transforming university and programs (including interdisciplinary EE) and rooted in community. Community outreach activities included in a postgraduate setting include student consulting projects, incubator services, entrepreneur in residence, linkages with local entrepreneurship chapters and organizations, dissemination of research results to community, public symposia, industry and local government collaborations, technology transfer, consultancies, link with entrepreneurs, engineering organizations and internship opportunities and entrepreneurship alumni. The latter provide an invaluable source of referrals to entrepreneurship programs. An integrative approach to the audience dimension is the use of advisory boards and panels in the evaluation and development of EEPs. Such

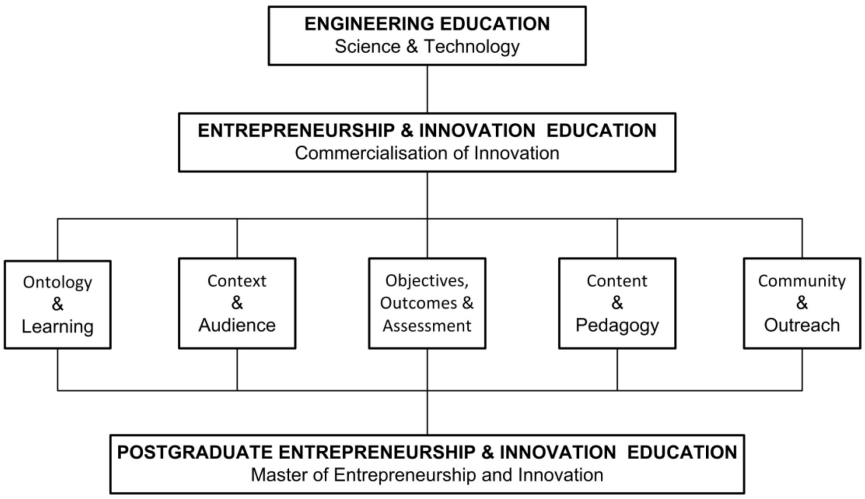

Fig. 1. A conceptual framework of a postgraduate entrepreneurship and innovation program targeted at engineers.

advisory board members provide a wealth of value to programs and institutions

The dimensions are represented in Fig. 1.

8. Conclusions

The aim of this paper has been to provide an overview and framework of EEPs and educational methods that effectively develop engineers in entrepreneurship specific postgraduate programs. To date, such contextualization has received scant attention in the entrepreneurship education literature. Our contribution in this paper is mainly to offer a conceptual framework in postgraduate entrepreneurship education for experienced entrepreneurs and engineers inspired by previous education sciences and current offerings in practice. This theory and practice-based approach to entrepreneurship education highlights important theoretical and practical implications.

We identified ten dimensions, an extension of the significant scholarly work of Fayolle and Gailly [11] and Maritz and Brown [1]. Dimensions included ontology and learning, context and audience, objectives, outcomes and assessment, content and pedagogy, and community and outreach. Ontology included adapted definitions of entrepreneurship, the entrepreneur, and entrepreneurship education. Learning for entrepreneurs included new insights to dynamic learning for engineers, including identification of teaching and learning philosophies. From an education and EEP perspective, we identified dimensions and significant insights regarding a heterogeneous context, a targeted audience, defined objectives, tangible and predetermined outcomes, assessment strategies, content validation and innovative pedagogical initiatives. The final dimension included insights into community and outreach engagement.

The predominant theoretical implication is the need to consider entrepreneurship education in a postgraduate context targeted at engineers. This paper has identified dimensions and issues of significance in this context, ranging from ontological, and education to community insights. The main practical implications concern program developers, educators, teachers and trainers in postgraduate entrepreneurship education for practising entrepreneurs. The paper sheds new light on the design and implementation of such programs.

Limitations include the use of predetermined entrepreneurship education models and frameworks, despite their perceived thoroughness. This paper provided an example of an internationally recognized and awarded EEP, and the opportunity exists to empirically evaluate such programs on a regional and global platform. Avenues for research could also include the analysis of learning for nascent and experienced engineers, as well as empirical studies on the effectiveness of EEPs using the above frameworks.

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