How could education systems cultivate knowledge-intensive entrepreneurship? An example from engineering education

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Abstract
This paper focuses on the role of education in the promotion of entrepreneurial activity among students and young university graduates. In particular, it examines the link between relative educational programmes that are designed to stimulate knowledge-intensive entrepreneurship putting special emphasis on engineering education. In this respect, the paper presents empirical evidence regarding the entrepreneurial activities of the Greek engineers and the knowledge and skills mix they are offered using survey work undertaken among graduates of the National Technical University of Athens (NTUA). Empirical work provides a) some interesting findings on the type and innovative performance of ventures NTUA graduates undertake and, b) the weakness of NTUA curricula in offering the necessary non-technical knowledge and skills that would assist young graduates in setting up entrepreneurial ventures.
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1. Introduction

Entrepreneurship has been studied as a key driving force of industrial dynamics and industry evolution (Malerba and Mckelvey, 2010). However, contemporary entrepreneurship research appears to be moving from a view that “all forms of entrepreneurship are good” towards a more nuanced view where “high-potential entrepreneurship” is an important driver for economic development (Autio and Acs, 2007; Henrekson and Johansson 2010).

Knowledge-intensive entrepreneurship can be considered as a type of high-potential entrepreneurship and indicates ventures whose initiation or expansion is based on the dynamic application of new knowledge. Also, new knowledge-intensive firms can play an important role in sectoral, local and national innovation systems by operating as problems solvers, knowledge brokers, knowledge-intensive service providers, or specialized suppliers.

The role of knowledge-intensive entrepreneurship as a mechanism that converts technological, scientific and market knowledge into economic activity has been gaining increasing attention among scholars as it has been realized that KIE offers opportunities (KEINS Final Report, 2008):

- To amplify the channels through which new knowledge is transferred and eventually transformed into commercial applications and thus to find and enter new market niches;
- To accelerate the exploitation of technological, market and institutional opportunities;
- To create new employment opportunities in new small firms which may even have the potential to grow;
- To attract and engage highly educated human capital into the process of adapting new theoretical and scientific knowledge to practical applications

One reason for the increased importance of KIE can be attributed to the fact that over the past three decades the share of scientifically educated work force is rising continuously in almost all European countries. This additional supply of highly qualified human capital cannot be fully absorbed only in the existing businesses and thus the need for new entrepreneurial activity becomes more significant (KEINS Final Report, 2008). Such highly educated people can have a background in applied sciences in the various engineering
disciplines as well as in new sub-disciplines in physics and chemistry (e.g. material sciences), in biology, medicine, information sciences etc.

Therefore, the need to strengthen the culture of entrepreneurship and risk-taking by fully mobilising human resources - through the improvement of entrepreneurship education- is acknowledged among top policy priorities worldwide (OECD, 2010). In this respect the role of educational systems can be decisive in increasing the prevalence and quality of entrepreneurial learning and thus in creating entrepreneurial mindsets that help entrepreneurs transform ideas into action. The function of higher education goes far beyond the delivery of knowledge and with high-tech and high-growth enterprises becoming a focus of entrepreneurship policies, higher education institutions can be considered as an active component of the innovation policies in Europe (European Commission, 2013). In consequence education institutions should ensure that they develop and promote a culture of entrepreneurship and innovation through their missions, stakeholder engagement, curricula and learning outcomes (European Commission, 2013).

During the previous decades a significant progress towards entrepreneurship education has been achieved changing the way universities function; however, there is still a lot to do ahead. Traditionally, educational institutes and especially universities were considered to be theoretically-driven institutions therefore new venture creation, which is definitely a practical effort, was always considered to be difficult to teach. Moreover, substantial resistance has been presented by educators who tend to focus upon their particular disciplines, which is incompatible with entrepreneurship training in cross-disciplinary settings (Bager, 2011). Thus the real challenge for the coming period is the transformation of the European educational systems so that they can stimulate entrepreneurship, especially the knowledge-intensive one.

In this paper we focus on education as a key enabler in promoting high-potential entrepreneurial activity. In particular we concentrate our study on how education could promote engineering knowledge-intensive entrepreneurship and we provide provide some empirical evidence on the characteristics and innovative performance of the entrepreneurial ventures undertaken by young engineering graduates in Greece. In this way we try to shed some light on the features of entrepreneurial activity exercised by people that are assumed to have the capacity to set up knowledge-intensive ventures. Furthermore we provide evidence on the knowledge and skills received by engineers during their undergraduate
studies in order to better understand whether engineering education in Greece represented by the National Technical University of Athens has the capacity to address the needs of a global economy and foster an understanding of the relationship between engineering and business operations in the formal training of engineers.

2. Education and knowledge-intensive entrepreneurship

Cultural variables interact with economic and technological developments or with policies designed to advance entrepreneurship and can play an influential role in the decision of individuals to start a new business (Wennekers and Thurik, 1999). The development of an entrepreneurial culture through educational systems could be a means to stimulate entrepreneurship and thus enhance economic growth. In this section we focus on how educational systems could promote knowledge-intensive entrepreneurship since knowledge, as a result of externalities and spillovers, is particularly important to macroeconomic growth (Romer, 1986; Lucas, 1993).

An initial definition of knowledge-intensive entrepreneurship, proposed by Malerba and McKelvey (2010) in the theoretical framework of the AEGIS project, stresses new firms that are innovative in terms of economic value creation and present an activity which includes substantial amounts of knowledge. These new firms are not limited to high-technology but permeate diverse sectors (traditional sectors, manufacturing and services, existing and new industries). Consequently knowledge-intensive entrepreneurship is a complex phenomenon which transforms knowledge to innovation regardless of the type of venture and/or sector. There is no doubt that substantial amounts of knowledge are produced in certain institutions (i.e. universities, firms) that if or when diffused outside these institutions would result in a strong positive effect on the standard of living in our societies. The question is how this knowledge could be diffused. Audretsch and Keilbach (2007) have proposed a relative theory, the so-called knowledge spillover entrepreneurship theory. According to them entrepreneurship could function as the channel of transferring the knowledge produced from its source (specific incumbents (i.e. universities, other institutions / industries)) to the society. In particular, their work suggests that entrepreneurship is an endogenous response to opportunities generated by investments in new knowledge made by incumbent (source) organizations (firms, universities etc.) but which will remain uncommercialized due to the inertia inherent in decision-making under uncertainty known as the knowledge filter (Acs et al, 2004; Audretsch et al, 2006). The start-up of a new venture of this kind provides the
channel for the spillover of knowledge from the source organization to the new venture. In fact, all the uncommercialized knowledge produced is an important source of entrepreneurial opportunities waiting to be exploited by ambitious entrepreneurs (i.e. by the students, graduates, staff and outsiders who can benefit from their studies / interactions with the universities or by former employees who can diffuse knowledge produced but not commercialised in the institutions / industries where they worked etc).

The above theory could be of great importance for policy makers. By encouraging the exploitation of the knowledge produced but not completely or exhaustively commercialized, they could use knowledge-intensive entrepreneurship as the means to diffuse this knowledge to the society. The challenge for universities and policy makers is to find first, how to combine the entrepreneurship education efforts with the commercialization of the knowledge produced in the universities and second, how to create the entrepreneurial mindsets within the universities so that their graduates can exploit and diffuse uncommercialized knowledge wherever it is produced (i.e. in other institutions / firms or even by themselves).

In order to formulate a link between education and entrepreneurship resulting in the creation of entrepreneurial mindsets, researchers have initially suggested the introduction of stand-alone entrepreneurship programmes in the university curricula (business and non-business), focusing mainly on the appropriate content of these programmes and the process of teaching (a review of relative theoretical articles is proposed by Gorman et al (1997)).

However, most recent research has supported that entrepreneurship education cannot unfold its full potential unless it becomes a top priority rather than an add-on activity. In particular the development of an entrepreneurial culture and strategy is needed in the “new” university (Scharmer and Käufer, 2000; Gibb, 2006) and entrepreneurship education could serve towards this direction. In other words, the challenge is to move students from their normal distanced position into the field, instilling skills and letting them experience personally the role of the entrepreneur through simulations, role-play, field work and so on (Löhler, 2006).

Toward this direction, Bager (2011) proposed a “comprehensive” perspective in entrepreneurship training as an integrated approach to the way universities can facilitate the formation of student and graduate start-ups and enhance knowledge spillovers to society. According to this perspective, the entrepreneurship field cannot be separated from
the traditional business and management fields of finance, accounting, marketing, strategy and organization; however it approaches them differently, based on the venture creation perspective rather than the large firm perspective. For example discovering (or creating) a new idea, which by definition entails a gap to a possible future state, and evaluating a priori its chance of succeeding should be dealt systematically combining principles from different disciplines (Shane and Venkataraman, 2000). In particular, focus should be on developing the core competences of recognizing - evaluating - exploiting opportunities and building organizations in order to create entrepreneurial mindsets, behaviours and intentions and finally enhance knowledge spillovers from universities to the society through entrepreneurship (Bager, 2011). The “package” of initiatives and reforms that Bager (2011) proposes in order to build the entrepreneurial university includes several aspects: the formulation of an overall university strategy and top-management support; the offering of a variety of entrepreneurship courses (at both introductory and advanced levels); the enhancement of relative research to support teaching activities; the dissemination of innovation by furthering pedagogy and didactics in other fields; the introduction of extra-curricular activities such as events with “outsiders” and business plan competitions; the establishment of hatcheries and incubators; finally, the development of an entrepreneurial culture.

Until now we have seen how the university can develop an entrepreneurial culture and how this could influence young students and graduates in order to undertake entrepreneurial activity during their studies or after their graduation. On the other hand the effectiveness of the university system itself plays a crucial role not just because it affects the competence profile of the graduates but also because of the networks with the private sector that it develops and the level of the academic entrepreneurship it achieves.

Academic entrepreneurship (through academic start-ups, academic patenting etc) appears to be growing phenomenon Europe (Lissoni et al, 2007) and university spin-offs are becoming a significant global phenomenon exploiting a wide variety of different technologies (Shane, 2004). These university spin-offs are quite valuable for our societies since they push local economic development, contribute to the commercialization of university-made technology, promote university research and teaching by providing valuable feedback and generate more income for the universities than simple licensing (Shane, 2004). High-tech spin-offs are mostly found in the industries of biotechnology and computer
software and possible reasons for that is the reduced time required from academic research to commercializable outcomes, the concentration of the appropriate expert personnel in the universities, the value for money relationship, the patenting legislation etc (Shane, 2004).

However in new high-tech university spin-offs, the lack of experience on behalf of the entrepreneur combined with the novelty of the venture, constitute an important barrier in the struggle of the new venture to pass through the early stages of growth and become an established firm. Universities typically lack resources and academic entrepreneurs very often do not possess the commercial skills required to create ventures. Moreover conflicting objectives among stakeholders (universities, academic entrepreneurs, venture management teams, venture capitalists etc) create a complicated environment for the spin-offs (Wright et al, 2007).

3. Engineering education and knowledge-intensive entrepreneurship

As Fayolle et al (2005, p.1) put it “entrepreneurial engineers seem to be innovators and creators of economic wealth”. However the entrepreneurial and innovating behaviours of engineers are heavily affected by cultural factors (national, professional etc). Since these factors are either favourable or unfavourable to entrepreneurship it is important to understand the relative mechanisms and their impact on the educational systems in order to find ways to stimulate knowledge-intensive engineering entrepreneurship.

As far as national cultures are concerned, Fayolle et al (2005) support that, in France, for example, the evolution of the role of the engineer in the industry and its correspondent social status formulated a cultural approach (illustrated also in the educational system) that discourages engineers from obtaining an entrepreneurial position. In fact the most famous engineering “Grandes Ecoles” prepare their graduates for a prestigious career within large companies and administrations and ensure that there are strong networks of graduates and relative “elites” that will assist the fulfilment of such endeavours. Moreover the title of qualified engineer is protected by the “Commission des Titres d’ Ingénieur” so it constitutes a discriminatory element which is of significant importance within companies.

The above stated cultural approach in combination with the emergence of “professionalism” as the main accepted source of authority (authority justified by the manifested competence instead of the position in the hierarchy) resulted in two types of professional identity for the French engineers: ability to manage people and technical expertise (Lasserre, 1989). None of them includes the entrepreneurial behaviour.
Professionalism and technology-orientation were also stressed by the German engineers who tend to follow a career within big organizations; however a shift towards market orientation was found by Fayolle et al (2005). On the other hand there are engineers, like the Dutch ones, who may be less specialized in the technical area than their German colleagues but they are traditionally more market - oriented. It seems that, as far as the professional culture is concerned, a significant transition in the engineering culture towards market orientation is taking place.

Regarding the engineering curricula, emphasis is usually given to the development of strong technical culture. This, in turn, results in the creation of specific behaviour patterns and ways of thinking which make it difficult for engineers to take into account what is not measurable. The absence of management training in engineering schools was identified so, eventually, more and more engineering schools include relative training in their curricula, mainly in economics and management (Fayolle et al, 2005).

In this environment which discourages entrepreneurship, there are however, engineers who finally decide to become entrepreneurs. According to the research of Fayolle et al (2005) the main drivers that result in engaging in engineering entrepreneurship include: the school of origin (engineering schools that promote active interaction with training as seen by engineers as institutions that develop entrepreneurial behaviours), the type of training and specialisation (a generalist training provides wider opportunities and thus can lead to entrepreneurial activities away from the original engineering specialisation whereas a specialist training provides technical expertise that can lead to entrepreneurship based on the technical aspect of the product or the service offered by the new venture) and the previous experience (engineers prefer to act entrepreneurially, at least at the beginning of their entrepreneurial endeavours, in areas where they have worked in the past exploiting previous technical knowledge, skills, networks). On the other hand, as far as the day-to-day running of the new venture, building the relationship employer-employee on the basis of promoting innovation and creativity and working in teams are characteristics commonly found in the new ventures created by entrepreneur engineers.

As far as the professional culture is concerned, Fayolle et al (2005) distinguish two types of entrepreneur engineers in their research: the manager entrepreneur engineer and the technician entrepreneur engineer. The former is the engineer who eventually gives less emphasis on the technical dimension of his/her job before setting up (or acquiring) a
business whereas the latter is the one who remains concentrated on the technical aspect of his/her job before setting up (or acquiring) a business. These two divergent paths lead to different behaviours when creating a new venture: Having developed new, non-technical skills the manager entrepreneur engineer is described as an innovator or resource coordinator who does not hesitate to develop his/her entrepreneurial activity in areas that are not close to previous experiences or initial specialisations (for example in the service sector and especially in the consulting domain). On the contrary, the technician entrepreneur engineer is described as an inventor who very often creates a new venture in order to continue a technical project which started within the company where he/she worked but could not develop inside the company anymore. This kind of entrepreneur engineer seems to prefer innovating in technologies and products remaining close to scientific and technical fields where he/she feels comfortable. That is why he/she tends to delegate managerial functions to others.

Another aspect of the entrepreneurship that concerns the relative research has to do with the time period (within the professional life of the potential entrepreneur) when the relative activity takes place. Verzat and Bachelet (2006) support that in many cases the entrepreneurial intention occurs very late. More specifically, as far as engineers are concerned, Fayolle (1994) also found that many engineers become entrepreneurs late in their careers.

According to Verzat and Bachelet (2006) entrepreneurship should be approached as a trial-and-error process, the result of which is determined by the vision that the person has created in his mind (regarding his beliefs of what he is capable to achieve and his expectations about what he wants to become) and the effect of the environment in which the person acts. At the beginning of this process Tounés (2003) identifies the “entrepreneurial intention” (intention to adopt entrepreneurial behaviour) as one of the major early stages. So, it could be hypothesized that a kind of “entrepreneurial spirit” exists before the decision of setting-up a new business (Verzat and Bachelet, 2006).

Consequently, by developing the entrepreneurial spirit of young professionals we could probably shorten the period needed to see the entrepreneurial intention to be expressed. Verzat and Bachelet (2006) have proposed a model of promoting entrepreneurial spirit within young engineers (even in students who had no personal entrepreneurial spirit background). This model is based on the dynamic elaboration of professional identity and of
specific attitudes, behaviours and competence feelings. According to this, by being offered the appropriate mix of academic and pre-professional activities (internships, activities within associations etc) young students would progressively reach the desired state of realising what they are capable of achieving in their professional lives and what are their values - beliefs towards what they would like to become.

For Ginzberg et al (1951, quoted by Guichard and Huteau, 2001) this process consists of three stages: the exploratory phase (during which first-year students gather information by participating in discussions with experienced and well-trained personnel (lecturers, career advisors etc)), the crystallization phase (when students (at the middle of their studies) formulate their professional priorities according to their tendencies) and the “specification” phase (when students at the last year of their studies in general, make their “final decisions” regarding their professional future and begin to work on their own project. The appropriate entrepreneurial competences develop accordingly (Verzat and Bachelet, 2006).

To achieve the smooth and effective transition through the above stages new teaching methods that put the student in a real problem solving situation are needed. According to Gibb (1993), entrepreneurship teaching methods should invest on multi-disciplinarity and they should develop specific skills and attitudes that favour entrepreneurship. In particular, as far as engineering students are concerned, teaching methods that focus on altering the risk-aversion attitude (created in engineering schools due to the continuous dealing with well-defined problems and the relative search for a unique solution based on scientific methods and analytical thinking) should be used. For example: “action learning”, “learning by doing”, learning through experience, learning from one’s own mistakes, learning from other people (Garavan and O’Cinneide, 1994; Hartshorn and Hannon, 2002; Leitch and Harrison, 1999) are some of these methods.

To sum up, according to Verzat and Bachelet (2006) even if entrepreneurial orientation is weak, the progressive development of professional identity could be influenced towards entrepreneurship through the appropriate entrepreneurship education (encouraging group dynamics during the curriculum, setting innovation objectives, offering appropriate resources (time, consultant teachers etc)).

Similar conclusions have been reached from relative research concerning the Greek engineers. Empirical studies from Caloghirou et al. (2009) revealed the following as prerequisites for a successful professional engineering profile: adequate theoretical
background, excellent knowledge of the relative technological field, very good command of information and communications technology, adequate knowledge of economics and management, developed skills regarding project management, communication, negotiation and team-working. Moreover, as far as the update of the engineering curricula is concerned, the overwhelming majority of the engineers interviewed (1999-2000) proposed the development of non-technical competences, the encouraging of the use of ICT and the exposure to the fields of management and economics.

On the other hand, the fact that many Greek firms are low-tech SMEs (Liargovas, 1997) which they still use traditional management methods (Makridakis et al, 1997), creates a hostile environment for personnel with a higher educational background. As Liagouras et al (2003) put it; the Greek economy and especially the business sector, seem incapable to absorb the supply of high quality researchers and PhD holders (most of them graduated from well-known European and American universities and technical institutes). In this environment several engineers engage in entrepreneurial attempts either driven by necessity or as a means to escape from the unsatisfactory working conditions offered by their employers (latent entrepreneurship) (Papayannakis et al, 2008).

In this light, the introduction of entrepreneurship courses in the curricula of the Greek universities (focusing on knowledge-intensive entrepreneurship) could serve as a lever in the struggle of the country to modernize its economy. Papayannakis et al (2008) propose an interdisciplinary context of education which combines engineering and non-engineering factors in order to develop the necessary skills (managerial etc) to engineering students. This way they believe that both the quantity and the quality of entrepreneurial ventures in Greece could be raised.

More specifically, they propose the development of an “entrepreneurship curriculum” that will be offered to all faculties (chemical engineering, mechanical engineering etc) as a distinctive module. The programme will focus on the relative field of the students, with regard to the new professional demands for understanding economics and developing managerial and entrepreneurial skills. It will provide educational material analysing the whole entrepreneurial process and it will not focus solely on the start-up phase of a new business. Consultation and open dialogue are proposed in order to overcome established opinions regarding the profile of the engineer and the role of the publicly funded University in the new era.
4. Knowledge and skills required by engineers today

In this paper, we argue that enriching the human capital of a social group that is most exposed to scientific and technological knowledge, i.e. engineers, early enough (i.e. during their undergraduate studies), towards entrepreneurship will increase the specific weight of a particular kind of opportunity entrepreneurship i.e. technological entrepreneurship. This in turn can foster and upgrade the growth prospect and the development trajectory of the country. But, how enriching this type of human capital can happen? It is well argued that “mental thought processes that entrepreneurs engage in to discover, evaluate and exploit opportunities are not fixed and may be taught” (Acs et al, 2005). Thus, by providing engineering students in their curriculum the necessary business and market related knowledge as well as complementary skills, the engineering education system could empower them to better recognize and perceive technological opportunities during their career path and convert them to market opportunities and business ventures. In this respect, “technical thinking” and “engineering feeling” can be complemented during engineering education studies with a knowledge background on market and business environment understanding, managerial and strategic thinking and entrepreneurial feeling.

In the context of this study we have made a distinction between three domains of knowledge and skills that we consider as necessary for engineers nowadays:

The scientific-theoretical background and technical knowledge related to subject of their diploma, the acquisition of a basic background in economic and management, and the development of skills, and especially non-technical ones. The importance of the first domain for engineering education is self-evident and remains unchangeable over time. However, we believe that the last two domains deserve further examination.

It is worth noting that knowledge of economic and business management has always been a prerequisite for the evolution of an engineer in managerial positions within an organization. However, during the last two and a half decades there have been major changes in the profile and employment of engineers at the international level.

A significant change is closely related to the fact that the strict division of labour between technical and socio-economic problems is has negative implications for both economic units and society at large. Furthermore, the increasing complexity and uncertainty of contemporary techno-economic systems have made the made the traditional engineering profile out-of-date. In order to respond to new changing requirements most technical
universities in advanced countries have modified their curricula by upgrading not just the courses in economics and management, but also in social sciences in general.

According to De Neufville (2001), traditional and long-established engineering curricula have failed to meet the need for examining the economic, management, regulatory and political aspects of technological systems which albeit have a central role in the design of these systems. More specifically, he argues that the effective design of a complex technical system requires the understanding and control of different managerial and organizational procedures, the careful organization of decision making and the process/product development processes, and the efficient coordination of the technical teams responsible for different sub-systems. He concludes that the solution to this problem could lie in the introduction of engineering curricula that combine/integrate in an effective way a strong technical education with business management and public policy domains. Therefore De Neufville proposes that engineering students today should follow high-level management/policy courses and in addition should undertake specific cases/practice work that would help them in combining their technical knowledge with knowledge in business management and policy.

The crucial role of skills in engineering education is also an important change in the last twenty five years. Today, the pattern of the technical university which aims to transfer as much knowledge as possible is considered out-of-date. On the one hand, the obsolescence of knowledge is so rapid that it tends to coincide with the time needed for its transfer. On the other, the boundaries between the different areas of engineers’ specializations are becoming increasingly vague. The diffusion of computer technology in all technical or non-technical areas and the emergence of new interdisciplinary areas of employment (i.e. environment) seem to be the fundamental causes for the blurring boundaries between the traditional engineering disciplines. In this environment, skills have a significant precedence over technical knowledge. Amongst the preferred required skills are analytical thought, adaptability capability to learn how to learn, initiative in taking decisions, etc. For instance, Torres et al. (1997) argue that “The contemporary engineer must be able to (a) effectively communicate orally as well as in writing, (b) be capable of working in multidisciplinary teams, (c) be able to attack problems with a global and multilateral focus, (d) have an entrepreneurial spirit, and (e) be sensible to his cultural, social and economic environment” (p. 738). Therefore there is no longer adequate for engineering students to graduate with
strong technical skills. They also need a broad range of skills and knowledge beyond that of the technical nature (Ohland et al., 2004). Specifically, engineers need entrepreneurial skills.

The modern enterprise increasingly resembles a ‘community of people’ (Heckscher and Adler, 2007) or a ‘system of resources and skills’ (Barney and Clark, 2007), the management and administration of which requires special knowledge, experience, skills and abilities that are not only technical and/or economic and managerial. The importance, for instance of social skills, leadership skills or the ability for a broader understanding of the business and socio-economic environment is constantly increasing and the development of this type of skills and competences in the university curricula context is now been widely recognized.

In general, there is an increased demand for graduates that do not only have technical competence but also a range of higher-order skills, such as communication skills, networking, leadership etc. as well as knowledge in management, entrepreneurship, financial analysis, product development, etc. Education curricula should therefore provide undergraduate students with the right mix of skills and knowledge that would allow them to be able to respond to the challenges posed by the business and market environment today.

In the next two sections we provide some empirical evidence on the characteristics and innovative performance of the entrepreneurial ventures undertaken by young engineering graduates in Greece. In this way we try to shed some light on the features of entrepreneurial activity exercised by people that are assumed to have the capacity to set up knowledge-intensive ventures. Furthermore we provide evidence on the knowledge and skills received by engineers during their undergraduate studies in order to better understand whether engineering education in Greece represented by the National Technical University of Athens (the most prestigious technical university in the country) has the capacity to address the needs of a global economy and foster an understanding of the relationship between engineering and business operations in the formal training of engineers.

5. Data and methods

The National Technical University (NTUA) is the oldest and most prestigious educational institution of Greece in the field of technology, and has contributed unceasingly to the country’s scientific, technical and economic development since its foundation in 1836. A large number of its graduates have performed very successful careers in business, public
administration and university education (including a good number of distinguished professors in Europe and the USA).

The NTUA is divided into nine academic Faculties, eight being for the engineering sciences, namely, Civil Engineering, Chemical Engineering, Mechanical Engineering, Naval Architecture and Marine Engineering, Electrical and Computer Engineering, Mining and Metallurgical Engineering, Rural and Surveying Engineering), including architecture, and one for the general sciences. All degree programmes require five years of study and provide students with a variety of courses and laboratory practice. NTUA follows the continental system of engineering education offering two years of theoretical (science) courses and three years of more applied courses that require advanced knowledge in specific topics.

Empirical evidence is based on survey work carried out in the end of 2007 by conducting telephone interviews with NTUA graduates using a structured questionnaire. The survey population was extracted out of the sample of a previous research on the career path and employment opportunities of NTUA graduates conducted in 2005 among young engineers i.e. graduates that have received their professional license from the Technical Chamber of Greece between 1996 and 2001. In the context of this earlier research we came across 781 engineers that either expressed the intention to undertake some kind of entrepreneurial activity or were already entrepreneurs. We came back to the same people two years later (2007) in order to check up on their employment status. We managed to get a response from 389 of them collecting in total 387 usable questionnaires.

The majority of the respondents (64%) in our sample confirmed that they were entrepreneurs - 46% have been continuing their entrepreneurial activity since 2005 while another 18% which were latent entrepreneurs in 2005 appear to be involved in an entrepreneurial venture two years later. 36% of our sample accounts for engineers who had reported their intention to undertake some kind of entrepreneurial activity in 2005 however they haven’t done so up to the end of 2007.
6. Descriptive statistics results and discussion

6.1. Venture demographics and innovative performance

In their vast majority the entrepreneurial ventures set up by the NTUA graduates are sole proprietorships mainly in the services sector with the dominant presence of construction and business consulting services (Table 1). The increased presence of ventures in the construction sector can be mainly attributed to the fact that a large part of the civil engineers, architects and rural and surveying engineers are traditionally setting up small technical offices. It is also important to indicate that the initial idea for setting up a business appears to be primarily related to the engineers’ undergraduate studies (84.4%). Therefore there is a close relationship between the entrepreneurial activity undertaken and the founders’ scientific specialization acquired during its undergraduate studies.

Table 1: Distribution of entrepreneurial ventures in terms of economic activity

<table>
<thead>
<tr>
<th>Sector of economic activity</th>
<th>No of ventures</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>156</td>
<td>64.2%</td>
</tr>
<tr>
<td>Other consulting services</td>
<td>36</td>
<td>14.8%</td>
</tr>
<tr>
<td>Other consulting services of the private sector</td>
<td>15</td>
<td>6.2%</td>
</tr>
<tr>
<td>Information technology</td>
<td>11</td>
<td>4.5%</td>
</tr>
<tr>
<td>Energy</td>
<td>8</td>
<td>3.3%</td>
</tr>
<tr>
<td>Trade, transport and storage</td>
<td>6</td>
<td>2.5%</td>
</tr>
<tr>
<td>Environment</td>
<td>5</td>
<td>2.1%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
The NTUA graduates that have been involved in entrepreneurial action were asked to indicate whether their venture was fully established or still in the development phase. Only a small percentage of ventures were found to be in some stage of their founding process (11.7%) while the rest of them had already been in operation for 6.3 years on average. Therefore the entrepreneurial ventures we are focused on are primarily young ones (81% of them had been operating for less than 10 years in 2007).

The specific business ventures were financed mainly from own resources (61.3% were funded entirely by own resources) and secondarily by family resources (14.4% were funded exclusively by family members). Equally impressive is the finding that there was extremely limited financial support from other funding sources such as banks, national and/or European subsidy, and venture capital funding.

In their grand majority (94%) NTUA graduates reported that they had set up micro ventures employing less than 9 people. Most interestingly, 40% of these employ just one person indicating that in essence they are self-employment ventures. 5% of the ventures can be considered as small firms and only 1% (just 2 firms) were found to employ more than 50 people.

![Venture size in terms of employees](image)

Figure 2: Venture size in terms of employees (N=243)

The best part of these ventures is addressing the national or regional market (88%) and only a small percentage of them appear to have an export orientation (12%).
Only 23.4% of the NTUA graduates (57 out of 243) reported that their firm has introduced a new or significantly improved product into the market. Table 1 indicated that among them only 1 venture appears to have introduced a new-to-the world product, while the majority of innovative firms (70.2%) have introduced improved products at the national level.

**Table 2: Distribution of ventures in terms of innovation type attained**

<table>
<thead>
<tr>
<th>Innovation type</th>
<th>No of ventures</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>New product-national market</td>
<td>14</td>
<td>24.6%</td>
</tr>
<tr>
<td>New product-international market</td>
<td>1</td>
<td>1.7%</td>
</tr>
<tr>
<td>Improved product-national market</td>
<td>40</td>
<td>70.2%</td>
</tr>
<tr>
<td>Improved product-international market</td>
<td>2</td>
<td>3.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>57</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

The greater part (80.8 %) of ventures exhibit no income from innovative products, while a very small part of 3.5 % appears to have a large share of sales attributed to innovative products (81-100%) (see Table 3).

**Table 3: Percentage of sales attributed to innovative products**

<table>
<thead>
<tr>
<th>% of sales related to innovative products</th>
<th>No of ventures</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>185</td>
<td>80.8%</td>
</tr>
<tr>
<td>1 - 20%</td>
<td>10</td>
<td>4.4%</td>
</tr>
<tr>
<td>21 - 80%</td>
<td>26</td>
<td>11.3%</td>
</tr>
<tr>
<td>81 - 100%</td>
<td>8</td>
<td>3.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>229</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

Figure 3 indicates that only a small proportion of entrepreneurial ventures undertaken by NTUA graduates exploit or integrate extensively R&D results produced either in- house or externally (e.g. through university collaboration). More specifically, only 15.6% of the respondents appear to have incorporated to a large degree research results in their ventures. This finding is in line with the low innovative performance of these ventures. However, 54% of them appear to use extensively new technologies. This complies with a general observation resulting from several CIS studies which points out that Greek businesses rely more on using technology produced outside their boundaries than internally.
7.2 Knowledge and skills offered by NTUA to engineering students

Graduates that responded to the questionnaire (either actual or latent entrepreneurs) were asked to assess their level of studies at the NTUA based on three broad domains: scientific and technical knowledge, knowledge in economic and management and non-technical skills. They had to attribute a score ranging from 1 (low level) to 5 (excellent level).

Table 4: Assessment of the level of knowledge provided during under-graduate studies (N=387)

Graduates that responded to the questionnaire (either actual or latent entrepreneurs) were asked to assess their level of studies at the NTUA based on three broad domains: scientific and technical knowledge, knowledge in economic and management and non-technical skills. They had to attribute a score ranging from 1 (low level) to 5 (excellent level). Table 4
presents their assessment for the first two knowledge domains. The results indicate an excellence of NTUA regarding its scientific and technical background and its major weakness in providing knowledge related to economics and management in general. More specifically, the majority of the respondents (55.6%) consider the scientific and technical background of their studies as very good or excellent, while 74% of them report that they have acquired no (35.8%) or minimal knowledge (38.1%) in economics and business administration.

The weakness of NTUA in providing knowledge in economic and business is better illustrated in Table 5. The NTUA graduates that responded to the questionnaire (either actual or latent entrepreneurs) were asked to report whether they have been offered courses related to economics, management, entrepreneurship, business administration, finance etc., during their undergraduate or post-graduate studies. Data processing reveals that in general a relatively small percentage of them have followed economics and business and management courses. Most interestingly only a very small percentage of them (4%) have been offered entrepreneurship courses which is more or less an expected result taking into account the fact that entrepreneurship education was introduced quite recently in Greek universities (essentially after 2003).

Table 5: Engineering graduates offered courses in (N=387):

<table>
<thead>
<tr>
<th>Course</th>
<th>NTUA</th>
<th>Postgraduate studies</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrepreneurship</td>
<td>30.97%</td>
<td>76.19%</td>
<td></td>
</tr>
<tr>
<td>Management of technology and innovation</td>
<td>7.41%</td>
<td>67.99%</td>
<td></td>
</tr>
<tr>
<td>Decision making techniques</td>
<td>7.67%</td>
<td>64.55%</td>
<td></td>
</tr>
<tr>
<td>Operational research</td>
<td>11.38%</td>
<td>61.64%</td>
<td></td>
</tr>
<tr>
<td>Project management</td>
<td>19.05%</td>
<td>56.35%</td>
<td></td>
</tr>
<tr>
<td>Finance</td>
<td>30.16%</td>
<td>54.50%</td>
<td></td>
</tr>
<tr>
<td>Marketing &amp; market research</td>
<td>24.34%</td>
<td>53.97%</td>
<td></td>
</tr>
<tr>
<td>Business strategy</td>
<td>25.93%</td>
<td>44.71%</td>
<td></td>
</tr>
<tr>
<td>Business administration</td>
<td>32.02%</td>
<td>40.74%</td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>31.75%</td>
<td>40.21%</td>
<td></td>
</tr>
</tbody>
</table>
Table 6 indicates that the complementary (non technical) knowledge and skills offered by NTUA during undergraduate studies are assessed, in general terms, as non satisfactory, especially when we take into account dimensions related to the understanding of the wider business environment (mean score 2.21) or the market analysis and opportunity recognition (mean score 2.42) i.e. two skills that are closely related to the engineers capacity to undertake entrepreneurial action. The mean scores representing the satisfaction of engineers in acquiring other non-technical skills that are considered as important in entrepreneurial activity (e.g. team-working, negation skills, taking initiatives, oral and writing communication skills) also indicate that these skills are not adequately cultivated during undergraduate studies.

**Table 6: Assessment of the contribution of undergraduate studies in building non-technical skills (N=387)**

Graduates were asked to assess the importance of including a series of courses related to economics, business administration and management, and entrepreneurship etc. into the NTUA curricula. They provided their perception using a five-point Likert scale where 5 indicates high importance and 1 no importance. The vast majority of the respondents report that the abovementioned courses should be included in a systematic way and across all engineering branches in the NTUA curricula. Most interestingly 62.2% of them highly recommend the provision of courses on entrepreneurship during their undergraduate studies.
Table 7: Importance of including the following courses in the NTUA curricula (N=387)

<table>
<thead>
<tr>
<th>Course</th>
<th>Important</th>
<th>Medium</th>
<th>None/Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project management</td>
<td>86,0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of technology and innovation</td>
<td>75,4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business administration</td>
<td>73,0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decision making techniques</td>
<td>71,7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>69,3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entrepreneurship</td>
<td>62,2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational research</td>
<td>57,4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business strategy</td>
<td>57,1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marketing and market research</td>
<td>51,5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance</td>
<td>46,6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The abovementioned findings regarding the mix of knowledge and skills provided to NTUA students indicate a gap in the curriculum regarding economics and management courses that should be taken into account when designing engineering curricula. This need becomes more intense given the increased interest on the side of graduates in these courses. Furthermore it is also identified a weakness in terms of the non-technical skills developed during undergraduate studies at the NTUA indicating that the curricula should address this issue in a more efficient way.

7. Conclusions

Entrepreneurship in general and more specifically knowledge-intensive entrepreneurship are seen as a means in order to create the knowledge-intensive economy of the future. Our educational systems could contribute towards this direction by developing the appropriate competences, stimulating the entrepreneurial spirit of the young students and providing initial assistance in their entrepreneurial activities. During the last twenty years several entrepreneurship-enhancing educational programmes have been implemented and their results have provided us with valuable feedback in order to proceed to further improvements, especially in stimulating knowledge-intensive entrepreneurship.

As far as engineering entrepreneurship is concerned, while it is agreed that graduate engineers are usually equipped with adequate technical knowledge in order to respond to their duties in their professional lives, it has been argued that cultural influences along with
the orientation of the engineering curricula on developing technical competences discourage young engineers from engaging in entrepreneurial activities. However, evidence from the implementation of specific educational programmes on engineering students show that entrepreneurial spirit could be stimulated through the appropriate mix of entrepreneurship courses material and hands-on training. The development of non-technical competences, the exposure to the fields of management and economics, the provision of mentoring by senior entrepreneurs, the use of appropriate networks along with incubator facilities and seed financing constitute an integrated educational programme that could enhance knowledge-intensive engineering entrepreneurship.

Empirical work conducted in 2007 among young NTUA engineering graduates provides a) some interesting findings on the type and innovative performance of ventures they undertake b) the weakness of NTUA curricula in offering the necessary non-technical knowledge and skills that would assist young graduates in setting up entrepreneurial ventures.

NTUA graduates can be assessed as a group of people of increased capacity that can potentially undertake knowledge-based entrepreneurial activity. However, in their majority the entrepreneurial ventures undertaken can be characterized as self-employment. The firms established by engineering entrepreneurs are mainly sole proprietorships of very small size mainly in the construction sector and secondly in consulting services with no export orientation. However, these ventures are primarily related to the subject of their scientific specialization. All in all these ventures are extremely “shallow”, in the sense that they do not incorporate or integrate research results and they appear to have a limited degree of innovativeness.

Important prerequisites for enhancing the entrepreneurial capacity of engineers are the combination of “technical thinking” and “engineering feeling” with knowledge background on market and business environment understanding and development of strategic thinking and entrepreneurial feeling. Therefore the engineering curricula should advance the development of non-technical skills, the provision of sufficient knowledge related to economics and management, the injection of a culture promoting creativity, initiative and entrepreneurship

Last but not least the engineering curricula should help students and young graduates realize that
a) A strategic, organizational-managerial, and economic perspective is necessary for any activity type (R&D, production, marketing, management and organization of industry and technical projects), employment status (entrepreneur, firm employee, public administration employee) and position.

b) The engineer is considered as a leader in his work environment, and
c) An engineer’s career usually follows a cycle: beginning from the execution and design of specific tasks to the design and management of projects or ventures (corporate on new ones).

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