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The Evolution of Engineering Management Education*

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This paper provides a comprehensive overview of the history of engineering management and clearly shows the various phases, both at national and international level, that finally culminated in the commencement of a graduate degree program in engineering management at the University of Naples Federico II and its subsequent evolution to entrepreneurial engineering. Nowadays, the relevance and the strategic importance of engineering skills in the development of innovative businesses and organizations motivates the investigation of the role of the engineer in society. The new figure of the engineer-entrepreneur is so complex and multi-dimensional that it becomes very important to collect contributions of literature from distant areas of investigation not strictly related.

Keywords: education history; engineering management; entrepreneurship; engineering skills; managerial skills; entrepreneurial skills

1. Introduction

The introduction of a degree course of engineering management allows engineers to acquire both technological and managerial skills. Starting from an analysis of the body of literature on the topic and the existing degree programs in engineering management, this paper has two main aims: to provide a useful starting point for future surveys and research on both managerial and entrepreneurial university education, and to suggest policies that support entrepreneurship and business development. The identification of the different dimensions that characterize the entrepreneurial skills will provide guidance for future researchers and will hopefully inform public policies so that they may play a key role in supporting the entrepreneurial/third mission of universities.

2. The origin of engineering management

Modern engineering was born at the end of the eighteenth century, within the cultural season of the Enlightenment, and has always been proposed as a dynamic science inclined to all technical applications. In the twentieth century, the emergence of a variety of technical and scientific knowledge led to the rise of new areas of skills going from an ''all-comprehensive'' engineering to an engineering characterized by many specializations [1].

Nowadays graduate engineers, regardless of their area of expertise, are expected to be able to analyse and solve problems efficiently and effectively. Therefore, they are expected to have professional competences, leadership, creativity and communications skills as well as cultural awareness [2].

Engineering Management is a discipline which is meant to design, operate and continuously improve complex systems of people, machines, money, time, information and energy [3] by integrating engineering and management of knowledge, skills and techniques in order to achieve desired goals in a technological enterprise, while preserving the environment, quality and ethics [4]. Engineering Management has been also defined as the discipline whose aim is to make operational and strategic decisions in current and emerging technologies, evaluating their impacts on related systems [5].

The history of engineering management stems from the transformation of the role of the engineer in society during the twentieth century, while the engineers were at the forefront of modernising industrial processes.

The organizational and structural changes which took place within companies and the emergence of an industrial society based on multiple interrelationships led to the transformation of engineering education. Even though this process of transformation reached maturity after the phase of the economic growth in the late fifties in Italy, it is certainly true that the progressive approach to integrate subjects whose focus are not technical/technological into engineering education is something much older and just developed outside the borders of Europe [6].

A pioneer of these changes was Frederick W. Taylor, founder of what is known as a true ''managerial revolution'' between the late nineteenth and the beginning of the twentieth century. In the same period in the Yale and Towne Manufacturing Company, located in the city of Stamford (Connecticut), President Henry R. Towne started a deep restructuring within the company. Although the restructuring was not as successful as Taylor's revolution, it undoubtedly facilitated the beginning

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of a wide-ranging debate on the efficient management of an industrial enterprise and the role of engineers.

In a speech of 1886, titled *The Engineer as an Economist*, Towne stated that in order to ensure a growing business, it was necessary that the management and organization of productive work was entrusted not only to people with knowledge of the various types of production processes, but also, to those with executive skills of how to observe, record, analyse and compare salaries, supplies, expenses and any other issue that was going to affect the economy of production and the cost of the finished product. The ultimate goal of Towne was to unify in a single figure the mechanical engineer and the manager.

Other early pioneers were Harrington Emerson, Henry Gantt, Frank and Lillian Gilbreth [7].

3. Why start from the experiences overseas?

It is important to find out why the commencement of a serious debate on the figure of the engineer started in the United States in the second half of the nineteenth century. At that time, the difference between American and European mechanical industry was precisely the idea that a division of finished products into many perfectly interchangeable parts would increase output and meet such a broad and growing domestic market. Large enterprises, more and more technologically advanced and complex from the organizational point of view, need professionals that would make their organizational structures and internal processes functional and efficient. Due to their analytical ability to solve problems, the professionals more experienced to meet these needs were the engineers. These needs tended to remove the engineer from his traditional occupation, exclusively devoted to designing, giving him a more flexible role within the company and turning him into an *engineer-manager*. The second reason why these theories were developed in the United States is because of the different educational training received during the nineteenth century by American engineers; education was characterized by a particularly pragmatic approach and was much closer to the everyday problems that a manager of a large company could encounter, but less focused on the theoretical aspects compared to its European counterparts, reflecting a society less elitist and characterized by greater social mobility. It was a widespread business practice in the United States to entrust the highest managerial positions to engineers.

It was this awareness that led to the push towards the introduction of the social sciences in engineering schools. There were several cases of engineering schools modifying their curricula by introducing courses such as the organization of work, economy, finance, costing, business law and marketing. The most prominent case was the administrative engineering course at MIT, which was established in 1913 and later became the Sloan School of Management after the Second World War [8].

The first Engineering Management course in the U.S.A. began at the University of Missouri-Rolla in 1967 [9]. This University also awarded the first Engineering Management doctorate of philosophy in 1984 to Madison Daily.

The field grew slowly until the oil crisis of the 1970s in terms of both the professional area of expertise and the number of degree courses established [10].

By the 80s, engineering management became a conventional field of scientific research. Although the field had been present in academic databases since the early 50s, it experienced drastic growth which manifested in terms of an increase in the number of articles, journals and conferences on Engineering Management by the end of 80s. Between the 80s and 90s, engineering management achieved more growth in terms of papers and sources. The 90s and 2000s were characterized by specialization and professionalization of the field with the establishment of many dedicated degree programs in engineering and technology management [11].

In the same period also in other continents, such as Oceania, there was the growing need to revise the universities engineering curricula. In 1991 the Council of the IEAust (Institution of Engineers, Australia) established that the engineering undergraduate courses have to provide at least the 10% of management content by 1995.

The impact of this disposition had a great impact on the undergraduate engineering programs at Australian Deakin University. A survey conducted in 2002 and carried out in a sample of 135 graduates from the period 1996 to 1999 ranks the importance of managerial skills acquired during their undergraduate engineering programs [12].

The difference between overseas and European countries was confirmed by France, one of the European countries which has a strong engineering tradition and a strong hierarchical education system, in line with the rigid and hierarchical structure that characterized the national community of engineers. At the École Polytechnic, absolute priority was given to mathematics and deductive approach, based on in-depth study of geometry and analysis. Little attention was devoted to technology and applied sciences. Social sciences however, made their appearance only in the lower level courses.

As in the United States, engineering education in France did not match the role that engineers assumed in the company at the end of their educational program. Most of them dealt with the organization and management of a large number of public engineering projects and also, with the analysis of feasibility of several civil engineering projects from technical, economic and safety points of view.

4. The Italian answer to changes overseas

The first attempt in Italy to systematically introduce social sciences as part of the courses offered by a polytechnic institute dates back to 1934, with the establishment of the School of policy and business organization at the Polytechnic of Milan.

Following the example of what happened in the United States, the Polytechnic of Milan decided to improve the curricula of engineers. It was a *post-graduate* specialization course based on transversal notions of economics, organization and theory of enterprise, mainly intended for production engineers. By so doing, new subjects entered into a technical school: theory of management, technical and economic policy of enterprise, administrative and commercial organization of enterprise, systems and methods of sale, technical exports and characteristics of complex mass industries.

The course achieved good result in terms of enrolment in its first year, with 38 members and 16 auditors. The achievements recorded in the first year was followed by ups and downs in subsequent years, which was an indication of the difficulties that would later characterize the introduction of these subjects into Italian schools of engineering.

During the crisis of the thirties, the introduction of Taylorist and Fordist production techniques took place through a careful process of adaptation of the latter to the Italian economy.

Among the protagonists of these processes of adaptation to the Italian situation were Fiat and Olivetti. In the post-war period, these ideas developed overseas at the beginning of the twentieth century, which had appeared briefly in Italian and European history in the following decades, returned.

In Italy, from the second half of the fifties, conferences on the transformation of the role of engineers were organized in the most advanced industrial sectors in order to understand what the future of the country would be. In some industries, the complex nature which organizational processes were assuming, gradually modified the functions of corporate executives, who in most cases had an engineering background.

The former technical director of Olivetti, Gino Martinoli, emphasized this in the early sixties. During a speech at a conference in the spring of 1962, Martinoli pointed out the importance of research work published during those months by the Centre for Statistical Studies of the University of Pavia and Assolombarda.

It was a survey conducted on a sample of more than 1.000 graduates of technical universities of Turin and Milan. From data analysis, it was discovered that "only 14% of the graduates performed design activities while the remaining 86% had managerial functions in the field of administrative, commercial and technical".

Despite "the lack of those social and organizational teachings and disciplines intended to prepare the engineers for management tasks", companies preferred "technicians from schools of engineering" relying on their basic training and above all, on the "subsequent natural training based on the experience and natural talent" [13]. This choice however, made the process of integration of graduates in enterprises longer and less efficient, creating in them a general sense of dissatisfaction and inadequacy. This was true for small, medium and large enterprises.

However, the problem had a more global reach. The historian Lavista, in the "History of engineering management", claims that it was not only the faculty of engineering that was inadequate at the time but that the entire Italian educational system was affected by long years of immobility. This concept was also highlighted by a survey commissioned in 1959 by the Ministry of Public Education for the Association for the development of industry in the South (SVIMEZ).

In 1967, the Ministry of Education established the National Committee for the training and utilization of scientific and technical staff chaired by Agostino Capocaccia, then Dean of the Faculty of Engineering of the University of Genoa. The objective of the Committee was precisely to study how engineering schools could be reformed. Academics that are managers of companies in both the public and private sectors took an active part in the project. One of the very significant changes proposed by the Committee was the introduction of the social sciences in technical studies as a logical consequence of the fact that social sciences were necessary to govern complex corporate structures in which economic, cultural and organizational aspects assumed an increasingly important role.

In Italy, towards the end of the sixties, the faculties of engineering and polytechnics seemed to be fertile for the integration of economics related subjects. However, the reform of the university took place several years later.

5. Some Italian pioneering experiences

In 1971 it emerged for the first time the necessity to introduce into new or already existing faculty special courses of study targeted at those who need both technological and managerial skills [14].

Some pioneering experiences were taken in this direction and they involved the introduction of business management courses within technical faculties, without thinking about the design of an innovative graduate program for engineers.

The first action was the establishment of the Centre for the Study of Economics Applied to Engineering, founded in the sixties at the University of Naples and directed by Luigi Tocchetti. The centre played an important role in the modernization process of the study of engineering in Italian universities as well as in the future developments of engineering management.

Similar innovative actions played a major role in feeding the scientific debate. At the International Centre for Mechanical Sciences (CISM) in Udine on October 8, 1974, a meeting, titled *Systems Theory: guidelines and perspectives*, was opened after which the Group of Economics and Systems (GES), aimed at supporting collaboration between system engineers and economists, was constituted. In less than a year, the membership strength of GES rose to over a hundred members, reflecting the increasing interest in these issues. The city of Udine in later years would play a significant role in the history of management engineering. However, the complete reorganization of engineering would have to wait until the end of the eighties.

The commencement of a real first degree course in technical-economics was realised with the founding of a new university in the town of Rende, Province of Cosenza. In addition to three traditional degree courses in chemical, mechanical and electrical engineering, a graduate program in economics and organization, whose aim was to combine specific knowledge of economics and management with a robust technical knowledge, was started. It was in Italy that the first university course designed for engineers would meet the new needs of an industry that was advancing at great speed.

New courses and pioneering actions were quite successful and their effect spread beyond local boundaries, providing the motivation for further actions whose results were realized in different Italian and European universities.

6. The first European followers

In the same period, other parts of Europe began to follow the Italian example by establishing graduate programs which incorporate economic management education in engineering.

The Technical University of Denmark in Kongens Lyngby was the first in Europe to introduce a modular course in 1972 in order to open the school of engineering to new disciplines such as operations research and applied mathematics [15].

In the same period at the Catholic University of Louvain, a specialized course of civil engineering in industrial management was introduced [16].

Meanwhile, the Technical University of Czestochowa in Poland was pushing for the insertion of human sciences into the curricula of engineers. Alongside the traditional technological subjects, they were joined by other courses close to those found in modern schools of management, such as sociology and psychology, ergonomics, organizational sciences and law. Also teachings such as philosophy, sociology, political economy and fundamentals of political science were added [17].

Finally, the University of Glasgow started a postgraduate course in production management in 1975; it offered a course in general management in the first year which was followed by courses of quantitative methods for industrial production management, behavioural sciences, accounting, marketing, planning and production control, job design, materials engineering and business policies in subsequent years [18].

The experiences that occurred in the United States and Europe highlight how the attention to the introduction of economic and management studies in engineering were present in major universities and the University of Naples Federico II also followed this trend.

7. The birth of engineering management in Naples

The attention on the economic and organizational issues has a long tradition in the Faculty of Engineering of Federico II. When in 1956 Luigi Tocchetti became Dean of the Faculty of Engineering, his first concern was to know how the industry evaluated the engineers who graduated from Naples. For his purpose he organized a meeting with the leading managers and entrepreneurs and asked them: ''How do you evaluate graduates of the Faculty of Engineering that you need to use? Is it good for your needs?''. The answer was unanimous: ''Your engineers are complete in terms of scientific and technical knowledge, what they lack is knowledge of economics and business management''.

The academic world had underestimated these aspects that were required by companies and were essential to make not just a career but also, an independent professional activity. Worried by this

inadequacy, it established a complementary course whose contents concerned the basics of economics: how to read a budget, its main components, how to calculate dividend, what is cost of production, the cost of a unit of the product, what is a balance sheet, and so on.

With the founding of the *Fund for the South*, it was proposed that some members of this organization should stablish a Centre for Studies in the Faculty of Applied Economics to Engineering, which was known as CSEI. An agreement among the Fund for the South, the University of Naples, Formez and Svimez institutes, was reached to implement this idea. The Fund for the South financed the activities of the centre.

Other institutions contributed to its founding and activities without financial burden. On the basis of an annual program, which was submitted to the board of the Fund for the South, it provided the funding, which at that time was of the order of a few tens of millions per year. These funds were used to organize courses taught by professors of the Faculty of Engineering and other faculties, by foreign professors and members of the industry, and for the organization of seminars.

Hundreds of young people assiduously attended these initiatives. The Fund for the South had alternate experiences in Italy and the CSEI resented these events. When it was forced to suspend its activities due to lack of funding, all of its assets went to the Faculty of Engineering of Naples. This heritage strengthened the teaching of Economics and Business Administration, sowing the seed for the creation of a new undergraduate program. In a few years, the leaders of the faculty appointed a committee open to entrepreneurs, academics, Association of Engineers, Chambers of Commerce, representatives of the first experiences in Italy and all the stakeholders who were planning similar events in Italy.

The work was conducted a few years later in 1987. The committee was appointed by the Dean Oreste Greco (coordinated by Carlo Savy and the secretary Mario Raffa) to present a working proposal during a study day on engineering management. All the hundreds of Italian and European participants were asked a question: ''How different must or should be the professional figure of management engineer than traditional engineer?''

The committee's proposal on the structure of engineering management, which was in collaboration with dozens of speakers at the conference, concluded on a number of issues particularly on the need to start a graduate program in engineering management as soon as possible in Naples to meet the demand of the labour market.

To give an idea of the debate, some answers to that question are reported briefly. In his speech, Eugenio Corti pointed out the role companies have to play in dealing with the problems associated with technology. On one hand, it had to organize its technical and professional resources to investigate and examine in-depth the current technological knowledge, to predict future developments, acquire new technologies, and design new uses of existing technologies and new ones. On the other hand, the company had to deal with management of all available resources to achieve its strategic objectives.

It is important to note that in order to meet these requirements of companies, different professionals are needed. The first professional is a technical engineer who works in some parts of the process of technological innovation; the second professional required is an individual who plays a wider role in phases of the innovation process.

During the same conference, Giorgio Petroni supported the idea of extending for one year the duration of the degree course in Engineering. Gianfranco Dioguardi emphasized the importance of post-graduate education to train individuals to meet the needs of the labour market. In subsequent years, the implementation of the proposal and the improvement obtained during the conference led to the establishment of the degree course in Naples, which was strongly desired by the Dean, Oreste Greco, and enjoyed the support of the other deans, particularly Gennaro Volpicelli.

8. The skills of the engineer in society, technology and management

The degree courses in Engineering Management at the University of Naples Federico II started shortly after it was presented in 1987. It presented the features that have made the management engineer to be in great demand from business, public administration, and public and private research centres. This assertion was in agreement with the results of subsequent verifications.

In Naples on July 19, 2002 a meeting, ''The engineering management in the company and in society'', was organized to check to what extent the project of 1987, which was concluded some years later, met the requirements of the labour market. It was based on data related to the educational path followed by students in previous years and career paths that graduates of engineering management in Naples had followed.

It also took into account the advice of consultants, teachers, entrepreneurs, managers, professionals and representatives of institutions in order to compare it with the path followed until then. It was then to identify critical issues and developmen-

tal trajectories for engineers' educational program increasingly appropriate to the times. Also, on this occasion a shared vision emerged: the professional engineer was called to deal with the growing problems of organization and management related to technological innovation and its rapid evolution.

Alongside the usual areas related to the development of technology and its implementation in the production contexts and design, engineers tended in many cases to deal with, especially at more advanced stages of their careers, typical managerial issues ranging from project management to management of human resources, business organization and marketing.

Specifically, from the 60s to the present day, the relative weight of the technological skills, named hardware skills, compared to the organizational and managerial skills, named software skills, was gradually decreasing until it reached a substantial balance and subsequently a preponderance of the software on the hardware for some specific roles and professions which more than others lie on the border between organization and technology.

The relevance of software skills was also supported by the need for professionals and managers to make accurate decisions quickly in presence of limited information.

Experiments to test the impact of integrating management courses in engineering was carried out from 1987 to 2002 and verified during several meetings. They confirmed some issues concerning the knowledge and skills needed by management engineers:

- Besides engineers specialized in specific areas of technology, it emerged the need for engineers able to integrate technological, managerial, organizational and transversal skills in businesses and institutions.
- Transversal skills are very appreciated, even for specialized engineers. In fact, there were frequently in companies issues which did not require technical or specialized know-how to be solved, but the combination of a strong sensitivity to the technological problems and an equally developed sensitivity to economic, organizational and managerial problems.

To achieve this aim the Engineering Management education program provided a methodological knowledge base, technological skills, organizational and managerial skills, transversal skills (Table 1).

In order to acquire the knowledge and skills described above, an intense relationship with the entrepreneurial world was developed. As a result, nowadays the Degree Program in Engineering Management incorporates professionalism and experience (both academic and entrepreneurial) with the aim of responding to the new demands of the manufacturing and service sectors. There are also a number of external contract teachers, Italian and foreign.

Further, there are for all courses dealing with the problems of the company, a number of company experiences through which the operational problems that managers and experts face in their everyday life are presented to students.

The degree program has developed a number of tutoring services over the years in order to help the student both in training within the University and in their relationship with the world of business organizations and institutions.

The teachings of the Master Degree provide a set of cognitive elements related to the industrial structure of small and medium-sized companies located in Italy in general and in the south in particular. Subjects deal with the main variables that can affect the success and growth of small and medium-sized

Table 1. Knowledge and skills of the engineer: an overview

Cluster of skills	Definition	Fields, specific skills
Methodological knowledge base	Knowledge of the traditional engineering basic disciplines	Chemistry, economics, physics, mathematics, operations research, statistics, systems theory
Technological skills	Specialized technological know-how and the ability to use it to solve specific problems	In accordance with the specific engineer specialization
Organizational and managerial skills	Managerial skills for the management of technical-economic systems concerning the application of planning and control, the decision support, and innovation management of product and process	Analytical accounting, management control, finance, innovation management, personnel management, marketing, organizational behaviour, operations management, project management
Transversal skills	Transversal skills necessary to efficiently integrate the other categories of skills in professional and organizational contexts	Ability to work in a team, communication skills, knowledge of foreign languages, awareness of their professional and ethical responsibilities, problem solving, analytical thinking, ability to model problems

enterprises operating in different sectors, as well as those working directly for the market, and those operating as subcontractors for large companies.

Particular importance in this regard is given to issues relating to the management of innovation processes in small firms and technology transfer between large and small businesses. This privileged understanding of small businesses, their problems and associations has led to an important result: only 4% of the first graduates found work in small and medium-sized enterprises but today, the number is over 20%.

9. The recent evolution of the management engineer

Areas of professional opportunities for graduates in engineering management have a significant variety: apart from being able to work in companies (which constitutes about 50%), there is also a very strong component of the services sector, particularly in the advanced services, accompanied by an interesting n

It should be noted that the economic crisis that affects our country also affects graduates in Engineering Management to some extent. The number of employed graduates one year after graduation although high, has declined slightly in recent years.

Compared to other degree courses in engineering, the number of graduates in engineering management that create a new firm at the end of their course, becoming entrepreneurs, appears to be growing. This phenomenon now affects the majority of Italian universities and will require a more "entrepreneurship-oriented" university in the coming years.

At the time, start-up competition and the National Award for Innovation (PNI) involved more than half of Italian universities. They enable all professors, non-professors, researchers, PhD students, graduates, and students who have a business idea to organize themselves into working groups and enjoy a range of formal and informal supports in the transition from idea to execution of a business plan able to attract the attention of potential investors, and then get to the market. Support is offered to all groups in the design of the business plan, the creation and development of enterprise, with the chance to win cash prizes, and funding the entrepreneurial idea.

10. Knowledge and skills of engineer-entrepreneur

To show the role played by entrepreneurship in economic development of a country, a review of existing literature is necessary. The central nature of this topic demands contributions be collected from different fields of study that are not closely related for analysis. Entrepreneurship is increasingly becoming a complex phenomenon to be investigated. It can only be understood completely when looked at holistically (multidisciplinary approach) instead of looking at it from a particular discipline's point of view. Contextually, scholars who analyse the expertise of a potential entrepreneur are in agreement that the source of competitive advantage is often multifactorial and not attributable to a single set of skills [69].

The purpose of this section is to analyse the different dimensions of skills required to train an entrepreneur. This is done by an analysis of literature that shows the relationship between entrepreneurship and the theory of firms. According to the articles analysed, this paper identifies and classifies various dimensions connected with entrepreneurial skills and for each of them, examines the most significant specific skills. Specifically, Table 2 provides a set of factors supported by literature which characterize a new profile of the engineer-entrepreneur.

The first dimension analysed is related to the entrepreneur's personal skills necessary for the creation and management of an enterprise. The innovative dimension is based on literature related to Schumpeter theory and concerns the ways in which individuals can be innovative in what they do.

The financial dimension is related to the ability of entrepreneurs to raise funds and manage specific financial factors. The organizational dimension is related to entrepreneurship dispersed within the organization. The strategic dimension concerns future choices and a long-term vision for the enterprise. The relational dimension concerns the relationship between the company and the environment. Finally, the reputational dimension is connected to the generation of positive perspective about past and future actions.

11. Conclusions

The establishment of a degree program in engineering management was the result of a long process that began in the United States in the early decades of the twentieth century and later spread in several European countries including Italy. The engineering education did not seem to suit the role that engineers assume in companies at the end of their degree course. On the basis of what had happened in the United States, some Italian universities proposed to improve the curricula of engineers, introducing the teaching of a range of disciplines capable of increasing the knowledge of the students in the subjects of economics, organization and theory of the firm. Naples also followed this path, contributing to the

Table 2: Knowledge and skills of the entrepreneurial engineer

Cluster of skills	Definition	Fields, specific skills	Authors
Personal skills	Distinctive characteristics of the entrepreneur as a creator of business performance	Expertise, education, training, motivation, team leadership	(Vesper, New Venture Strategies, 1980) [19] (Cooper, 1982) [20] (Gasse, 1982) [21] (Smith & Miner, 1984) [22] (Duchesneau & Gartner, 1990) [23] (Vesper, 1990) [24] (Delmar & Wiklund, 2003) [25] (Littunen & Tohmo, 2003) [26] (Ferrante, 2005) [27]
Innovative skills	Types of skills that allow individuals to become innovative in what they do, producing a new product/ service or an existing good/ service in a new way	Cognitive skills, behavioural skills (e.g. the ability to solve problems, to manage risk), functional skills (e.g. basic skills such as writing, reading and numeracy) and technical skills (e.g. research techniques, project management, or IT engineering)	(Kleinschmidt & Cooper, 1991) [28] (Hitt, Hoskisson, Johnson, Richard, & Moesel, 1996) [29] (Zahra, Nielson, & Bogner, 1999) [30] (Drucker, 2001) [31] (Audretsch, 2002) [32] (Del Monte & Papagni, 2003) [33]
Financial skills	Types of abilities to raise funds. and manage specific financial factors (availability of internal resources, conditions of access to new debt, functioning of the credit market)	Accounting,, analysing data, auditing, budgeting, business analytics, cash flow management, cost analysis, crowdfunding, data analysis, decision making, investment principles, mathematics, risk management, taxation	(Roberts, 1991) [34] (Lee, Lee, & Pennings, 2001) [35] (Becchetti & Trovato, 2002) [36] (van Praag, De Wit, & Bosma, 2005) [37]
Organizational skills	A set of self-discipline measures to plan, implement the procedures, monitor growth and achieve set goals.	General organizing skills, planning, scheduling, coordinating resources, meeting deadlines and time management, analytical skills.	(Miller, 1983) [38] (Barney J. B., 1986) [39] (Corvin & Slevin, 1988) [40] (Eisenhardt, 1989) [41] (Corvin & Slevin, 1990) [42] (Covin & Slevin, 1991) [43] (Zahra, 1991) [44] (Cooper, Gimeno-Gascon, & Woo, 1994) [45] (Zahra & Covin, 1995) [46] (Lumpkin & Dess, 1996) [47] (McGrath & MacMillan, 2000) [48] (Lumpkin & Dess, 2001) [49] (Baum & Wally, 2003) [50] (Hayton, 2005) [51]
Strategic skills	A set of abilities to manage the tension between success in daily tasks and success in the long term considering the complex relationship between the organization and its environment	Strategy, internationalization	(Porter, 1980) [52] (Mintzberg, 1985) [53] (Porter, 1985) [54] (Hill, 1988) [55] (Dess, Lumpkin, & Covin, 1997) [56] (Hitt, Hoskisson, & Kim, 1997) [57] (Autio, Sapienza, & Almeida, 2000) [58]
Relational skills	Abilities of professionals to interact with each other, going beyond knowledge of business models and professional experience	Networking, listening, conflict resolution, confronting, encouraging, trust building, consensus building, mentoring, community building,	(Dollinger, 1985) [59] (Birley, 1985) [60] (Adrich & Zimmer, 1986) [61] (Stuart, Hoang, & Hybels, 1999) [62] (Baum, Calabrese, & Silverman, 2000) [63] (Lee, Lee, & Pennings, 2001) [35] (Davila, Foster, & Gupta, 2003) [64] (Elfring & Hulsink, 2003) [65] (Rodan & Galunic, 2004) [66]
Reputational skills	Types of skills to represent past and future actions positively creating a competitive advantage	Ability to generate a positive reputation	(Fombrun & Shanley, 1990) [67] (Fombrun, 1996) [68]

definition of a successful professional who has the appropriate skills to work both in businesses and public administrations, or to become an entrepreneur.

Because the new figure of the engineer-entrepreneur is so complex and multi-dimensional, it becomes very important to collect contributions of literature belonging to distant areas of investigation not strictly related.

In line with the articles found in the literature on the topic, this paper identifies and classifies the set of knowledge and skills required for the engineers. Furthermore, all these contributions are combined and correlated with both the theory of firms and the economic system.

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