The Internationalization of Engineering Education

Abstract: The fast development of industrial processes that involve production and serve international markets has created the need for a new breed of professionals that are as much at ease with technical problems as with the perception of market opportunities and international operations. Engineering education has been the first area of higher education to respond to the several changes that have occurred in the production process and the markets. This paper analyses the current trend towards the internationalization of engineering education, including the intrinsically necessary deeper interaction with industries, the entrepreneurial trend towards the creation of small, knowledge-based enterprises, and the mechanisms related to double degrees. The increasing importance of Engineering Education is not restricted to the education of Engineers in the POM area and should span the entire field of Engineering.

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Introduction

The main determining factor and the main tool in mankind's endeavors to dominate natural conditions by adapting them to its needs, thereby changing Nature, Man, and the relationship between them, is technology in the form of processes and means of production. From the production process of Paleolithic tools, which required different preparatory stages (i.e., projects) in order to achieve an end result (Leroi-Gourhan, 1975) (da Silveira and Meilrelles, 1994), to the mass production processes that characterized the Industrial Revolution, and on to the different farming techniques and different construction techniques that called for different forms of social organization that were associated with production processes which involved the performance of specialized tasks and therefore introduced several logistic problems , it is possible to rewrite the History of Mankind based on the History of Technical Skills, in other words, on the technological advances that changed the processes of production. (Warnecke, 1992).

The Industrial Revolution marked the beginning of a period in which these changes in the production processes started to occur at a much faster pace and for this reason, the term was coined and employed thereafter whenever technological change and the resulting economic and social changes gathered new momentum. Many historians usually classify such moments in three waves (Encyclopaedia Britannica), namely:

- The First Industrial Revolution, characterized by:
  - The use of empiricism to create knowledge (science, technology and procedures),
  - Agriculture becoming an industrial type of work (which is, essentially, a change in the production process),
  - The birth of factories (idem, aided by the advent of new power sources and by product standardization, which required the development of metrology).
- The Second Industrial Revolution, characterized by:
  - The decentralization of the power source (due to the advent of the internal combustion engine),
  - The production line (Ford),
  - Low-cost products affordable to factory employees (inception of the consumer society),
  - Automation and automated flow of materials and information,
  - The use of science to create knowledge,
  - The use of scientific methods in designing production mechanisms (Taylor),
  - The need for skills of a higher level, which called for better quality and required that elementary schools (at first) and secondary schools (later) be totally accessible to the social fabric, a decisive factor which marked North-American education throughout the 20th century.
- The Third Industrial Revolution, characterized by:
  - The decentralization of "intelligence" (a consequence of the overwhelming evolution of computers, computer nets and computer science),
  - The reduction of the intrinsic value of raw materials,
  - The microprocessor and machine decision-making and control systems, that perform the corresponding processes more accurately and rapidly than human beings,
  - The liberation of human beings to fully use their creativity as an important professional tool,

- The high value of innovation (new products with economic value), not only associated with large industries, but also with small businesses in the service society,
- The broader social reach of higher education and the capillary application of research results and knowledge to innovation, which is not necessarily associated with large investments of capital,
- High-speed telecommunications,
- The generalization of design procedures applications which consider uncertain factors (market, nature) and the customer/consumer's preferences,
- The concern (or political awareness, at least) with regard to the environmental, social and cultural impact of the technologies employed,
- The globalization of production processes and structures,
- A broader field of skills, knowledge and competencies for engineers, including entrepreneurship and business competencies.

The Engineering Profession

Engineering responded to the several waves of the industrial revolution by successively adding new missions to the career competency portfolio:

1. Technical competence (empirical engineering),
2. Scientific knowledge (science becoming part of technology),
3. Managerial command (administration becoming a scientific activity),
4. Social perception (entrepreneurial behavior) and international vision (global financial, commercial and production activities, and familiarity with foreign cultures).

See Figure 1

Actually, a fact that is more important than the addition of new missions and competencies is that the engineering profession has redefined itself in the course of the 20th century to the same extent that it has responded to new functions and needs by according different weights to the four dimensions shown in Figure 1. A classification that assembles the ideas in (Prados, 1998) with those found in (Lespinard, 1999) is given below:

(a) The period that immediately followed World War II: the <u>generalist engineer</u> with an essentially technical vision driven by the purchase and use of equipment, whose only concern regarded manufacturing processes for materials.
(b) The sixties: the <u>scientific engineer</u>, whose education would require a deeper knowledge of Mathematics, Physics and Engineering Sciences. This type of engineer would not be limited to the application of standardized techniques, but above all he/she would be able to develop and enhance such techniques based on an understanding of their functional reasons.
(c) Reactions: the <u>technical-specialist engineer</u>, whose education was the same as that of the generalist engineer, but conferred a deeper scientific basis in a specific technical area.
(d) The nineties: the <u>science-based entrepreneurial engineer</u>, whose education is described in ABET's and ABENGE's texts and in (Scavarda do Carmo et al., 1997), and who has served as a basis for the present text.

Engineering Education

Traditionally, Engineering Schools had always adapted to new situations when market and social changes were slow. As these changes began to occur faster and faster, it became necessary for Engineering Schools to start planning their own changes. This meant designing an "engineer production process" in order to attain the goals determined above in a unique context where one client – the student or the future engineer – is also the raw material, while the other client – the professional market and society as a whole – will be changed by the product, i.e., the engineering graduate. Furthermore, as a result of the increasingly faster rate of social change, this "engineer production process" needed to be continuously assessed and adapted to a new society and to new goals. In other words, Engineering Education became a continuous and rapidly-changing process that depended as much on careful planning as the industrial process did, and production and operations management (POM) became a relevant issue. See (da Silveira et al., 1995) for a first approach on the subject and (Scavarda-do-Carmo, 1997) for a few other considerations.

For example, the extension of human activities to all the corners of the world vis à vis individual polarization created two kinds of challenges for engineering education: internationalization and the development of entrepreneurial vision. The internationalization of Engineering Education is a response within the University to the global trend in terms of the production process. This is probably the beginning of a deeper process of internationalization of the University itself as an entity and of the Knowledge Factory involving the University and its connections in the productive sector. Entrepreneurial vision is indispensable in a society where technical requirements are based on the user's needs and desires, i. e., on the market, which is becoming more and more demanding and competitive. Entrepreneurship is an essential skill when working is considered more important than having a job. How can entrepreneurship and international skills be developed in engineering students? How can the engineering process be designed so as to attain such goals in today's society?

Example of a Case

These two questions were considered in a series of previous papers, as (Aranha et. al., 1997) and (Scavarda-do-Carmo et al., 2000), and the Double Degree Program, a novel structure that was especially adapted to the abovementioned goals, is an answer. The case study below explains the Double Degree Program between PUC-Rio and the four Écoles Centrales in France

The program at hand is not conceived in the same way as the usual "curriculum" or "student exchange program", where contents and activities are designed to develop competencies in the usual pedagogic sense inherited from Taylorism. Indeed, it is conceived as a group of experiences to which the student is submitted, namely,

- psychological challenges in which the desired attitudes are required,
- a production process where the student is educated by his/her own responses to the new situations to which he/she is exposed – under controlled conditions.

The purpose of this program is to insert students from both countries in courses in these countries and also to include periods of working internships in companies in Brazil and in France. The students will be treated by each institution as full-fledged students, and will have to satisfy the same requirements – which include attending classes that are taught in the country's native language – and the same advantages. Once they complete the courses, they will be granted diplomas from both countries, and this will allow them to work without any legal restrictions other than obtaining the agreed-upon job. The idea is to educate multicultural groups of students that have had a deep experience in different cultural contexts. The gain is not restricted to the acquisition of a multicultural education, but rather involves a new perspective that derives from comparing the relative importance of their native culture vis à vis a different culture by means of a more external and more conscious level of understanding.

The structure of the course is presented in Figure 2. When the school term begins in February/March in the Southern Hemisphere, the Brazilian students change countries in the fifth semester so as to begin their studies in France in August. This program is designed in such a manner that both groups of students remain together for four years in the two different countries, having taken the Core Courses in their native countries, the Common Professional Courses in France, and the specialization courses in Brazil. This combination is simplified by the fact that the models of the engineering courses in both countries are more or less similar. Both consist of an initial five-year period for study and the acquisition of a solid scientific education (Core Course). In addition, they have adopted a similar orientation that addresses the education of science-based entrepreneurial engineers with business vision and entrepreneurial experience, which is beyond the scope of the usual educational programs for Production Engineers. Evidently, the high level of education offered by the two Engineering Schools involved also helps.

See Figure 2

The entire program requires six years of study, which means that it is one year longer than the usual courses in both countries. Applicants consider this requirement reasonable, and it has the additional advantage of facilitating the curricular adjustments that the participating institutions will need to make. The students are expected to work annually as interns in companies throughout the last four years. At present, the organizers are seeking the support of a number of multinational corporations, all of which have expressed their enthusiasm for this new type of education.

At the moment, it is too soon to evaluate the Program because it is still being implemented. However, the multinational corporations that were consulted have revealed an interest in hiring possible former students (that do not exist yet, of course) immediately after their graduation.

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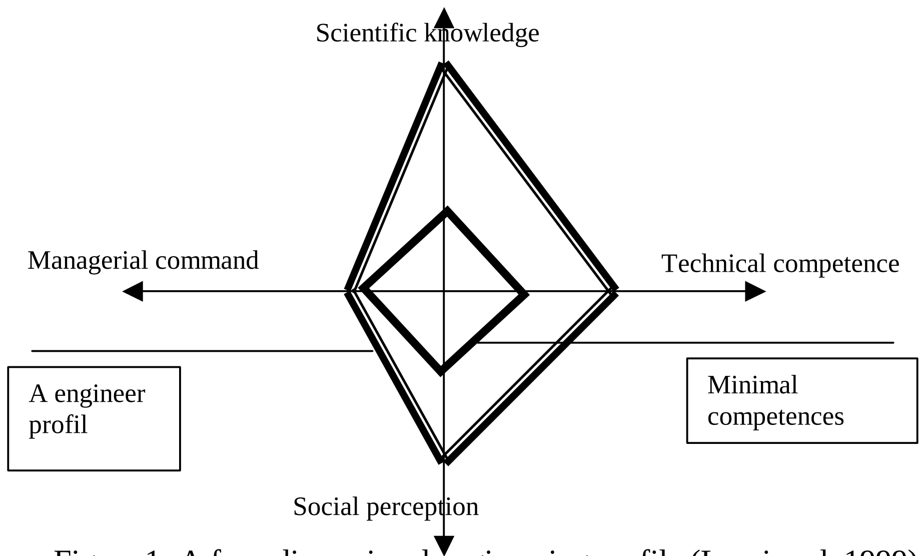

Figure 1- A four-dimensional engineering profile (Lespinard, 1999)

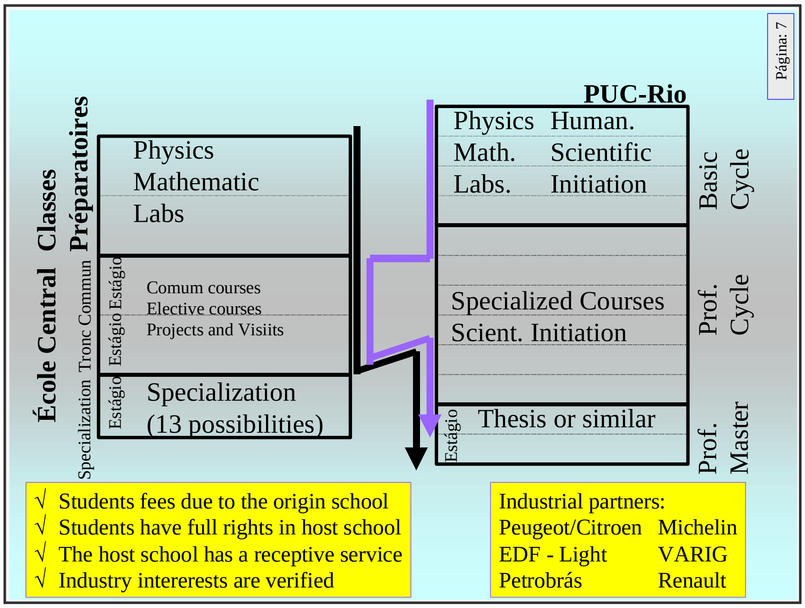

Figure 2: Schematic of the Double Degree Program between PUC-Rio and the Écoles Centrales.