The Engineer Role: An International Comparison

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Abstract - The engineer degree describes different functions and social roles around the world, as we can see from the set of the different denominations used, pointing to different functions and social roles: bachelor of engineering, master of engineering, ingenieur (Fachhochschulen), ingenieur (Technical Universities), incorporated engineer, chartered engineer, etc. The recent international agreements (Bologna declaration, Sidney 2001, Washington 1989, UEALC, etc.) created some general dispositions to the interpretation of such denominations, but there is still a need for a word on the different social roles and technical capacities. As an example, there are nine ways to attain an engineering function in France, only few being considered in the above agreements. The proposed paper presents a list of such social roles and technical functions for a number of developed and developing countries, which allows to clarify these questions. A correct answer for that matter is essential to a sound understanding of student interchange problems (the student mobility question), to successful double-degree agreements and to engineer accreditation issues.

Index Terms - formation profile, engineering degree, engineer social role.

I INTRODUCTION

Since engineers are more closely related to the image generated by the educational system, which is responsible for their education, the social role attributed to them is not to be mistaken for the technical functions they perform. We shall briefly discuss these roles while presenting a synopsis of engineers' educational profiles as they are proposed or applied in some major countries (from a technological standpoint) and in Brazil. Our main reference is [1].

II THE FRENCH MODEL

Schools of engineering were first established in France in the 18th century for the purpose of supplying the State with a technical cadre within the existing hierarchy of the government bureaucracy. First, the “military engineers”, who were to occupy technical functions in the Armed Forces. Then the “civil engineers”, in charge of bridges, roads, constructions in general and machines for the different “civil” ministries. Both groups were ensured quick ascent to managerial positions, either as a result of their qualifications and the logics inherent in bureaucratic hierarchies or because of the social background of their members and the extreme selectivity which is typical of schools where a limited number of admissions is available – thereby providing students with the certainty of eventually finding a job.

In the beginning, these engineers were “polytechnic engineers”, generalists with no substantial scientific bases, but who, on the other hand, mastered the ensemble of techniques of their time (which were still few in number and dissociated from the scientific knowledge of the time – see the Encyclopédie of Diderot and d'Alembert), although the school of choice did transmit a certain degree of specialization (École de Ponts et Chaussées, École de Mines, etc.).

Under the influence of Napoleon and Gaspar Monge after the French Revolution, engineering education acquired scientific bases, which led to the establishment of the 2+3 system: by obtaining good references in the Baccalauréat (high school final exam) students attended a two-year course at the Classes Préparatoires (essentially Mathematics, Physics, Chemistry, Philosophy and Cultural Education, in addition to which nowadays there is also Computer Sciences and Engineering “Principles”), and then took an admission exam at one of the Écoles de Génie, followed by a 3 year generalist education course. It was then which is then completed with some type of specialization during the third year and several apprenticeships in enterprises (performed as a curricular activity controlled by the schools). This educational profile may be referred to as that of a “generalist engineer with a scientific base”. With the development of the French industrial park, graduates from these schools moved straight on to management or project areas of private or state enterprises (as they still do), a fact that led courses to develop managerial vision as one of their major characteristics. For that reason in particular, major French schools today point out that the essential competence required from these engineers is to be capable of identifying and describing problems in terms that are convenient for their solution, and that their main

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attitude is to be one of entrepreneurship, which includes finding new market niches as well as new products.

Half way through the 20th century there were only eleven schools of engineering in France (the Grandes Écoles) wherefrom only a limited number of ingénieurs graduated, thereby guaranteeing a high degree of selectivity. During the two last decades of the last century, over a hundred Écoles de Génie were established, all of which with educational profiles according to what has been described above, occasionally either more specialized or more technical. The factors of selectivity and prestige here are always on a lower scale than in the former schools.

However, the number of graduated ingénieurs was, as it still is, always insufficient to meet the demands for technical positions in the French industrial park, especially for specific functions that are more directly related to industrial operations. This is where the hidden face of the French system reveals itself: there are more than eight ways one becomes entitled to perform the functions of an engineer needless of attending an École de Génie, not all of which grant ingénieur diplomas acknowledged by the French Commission des Titres (Lange, 1993). In order to illustrate these possibilities, we will describe a type of education on a more technical level: after the Baccalauréat, the students attend a two-year course in a university technical school (Institut Universitaire Technologique - I.U.T.) where they obtain a Diplôme Universitaire Technologique (DUT) and after a five-year experience in the industry they may enroll for one more year of complementary college studies, thus obtaining an engineering diploma. This type of educational profile may be referred to as that of a “technological engineer with a long education”. It is worth mentioning that this type of education is of highly specialized nature, and relates essentially to the functions of site engineers and factory floor engineers.

The two manners presented above for engineers’ education in France (École d’Ingénieurs and I. U. T.) are the most formalized. Costs per student (wholly state funded) are very high, especially in the first case. Most of the other manners involve the Facultés de Philosophie, Sciences et Lettres, originally structured with a view towards the education of professors and “cultivated men”, and imply far lower investments by the government – the cost per student in a “Fac” is much lower than in specialized schools and institutes. Therefore, despite repeated complaints concerning the inferiority of the “Facs”, and although not assuming it explicitly, the French government manages not only to solve the problem of providing funds for college education, but also to promote a keen selection among those who seek access to the main engineering education schools.

The social roles (also portrayed in literature and on screen) have thus been shown: the “management engineer” from the Grandes Écoles who originates from a smaller social stratum and masters the proper “ministerial” deportment along with a discourse that is finely tuned with the great power plays [2]: the “project engineer” or “technical adviser”, a graduate from the other Écoles de Génie who displays a technical-scientific discourse and is increasingly oriented towards the development of his own business; and the “operational engineer”, who does not bear the title of ingénieur, originates from another social stratum and whose future lies on the factory floor or in sales departments.

III THE GERMAN MODEL

By the end of the 19th century, in opposition to the French system, Germany organized an engineer educational system integrated into its enormously successful industry. The same system is repeated in Switzerland, Japan, Russia, Italy, and many other developed nations. It presumes two radically different types of education. In either one, the apprenticeship systems and the participation between industries and schools and courses are a matter of great pride to the Germans.

In the Fachhochschulen engineers receive education of an essentially technical nature for a period of three years during which they occasionally work as trainees in the industry, not so much importance being given to scientific bases. This educational profile may be referred to as that of a “technological engineer with a short education”, and, naturally, highly specialized. German society considers this to be the quickest way to gain access to a job in the industry, needless of having to waste excessive efforts in order to obtain whatever knowledge is not directly related to their objectives. Although in Germany no restrictions seem to be made keeping these engineers from holding positions in the direction of the companies, social expectations do not exert any pressure on these technicians leading them to further their studies in post-graduation courses (which was impossible until a short time ago).

The other diploma is obtained in a Technische Universität (former Hochschulen), after a period of five years according to the 2+3 scheme: two years dedicated to basic scientific studies and three years to studies in highly specialized areas, the conclusion of which is a final course project and the diploma thesis. No humanistic or managerial education is provided. Because they are always late in handing in their diploma theses as a consequence of the time spent in apprenticeships in the industry, it usually takes the student six years to obtain an ingénieur degree. This educational profile may be referred to as that of a “specialized engineer with a scientific base”.

Until 2002 a diploma from the Fachhochschulen did not provide legal access to academic complementation, the associated type of education considered as terminal. The Universität diploma bestows higher social prestige and grants access to the Doktorat – which is how top German specialists, researchers, project designers, advisers and teachers obtain their degrees. German unions indicate that high unemployment rates among German engineers are due to the fact that their education is oriented towards technical specialization. They say that 80% of the positions offered in the service and industry sectors seek engineers with some degree of education in management and (international, if possible) market vision – a feature which is not to be found in the German system. Aside from that, the Universität diploma
requires students to make heavy financial and intellectual investments without ensuring sufficient returns (by German standards).

Although German society seems not to discriminate engineers with a short education, the social roles associated to each of the two diplomas are different. Germans are respectful of the prominent specialists with a “Universität” education and seem to expect them to be outnumbered by those with a Fachhochschule education. Until a short time ago, diplomas and social roles seemed to be perfectly integrated into labor market functions and, therefore, they still appear in official statements. However, what the criticism of the unions and the emptiness of the Universität teaching labs reveal is a widening gap between the education which is supplied (top-rated with regard to their objectives) vis-à-vis the requirements of the labor market today. It is noteworthy to point out that engineers with a Universität degree are oriented towards technological innovation, although they are limited by their extreme specialization and their technical vision. Yet, German industry has been highly successful in this aspect.

IV THE ANGLO-SAXON MODEL

Engineer education in Anglo-Saxon countries is apparently simpler, although a different reality is shaded behind the curricular liberty of schools and universities. As Alastair Paterson notices, historically: “French engineers used to be the offspring of a certain kind of aristocracy, the great schools (Grandes Écoles). In England, engineers belong to a tradition that is both manual and of machine maintenance. Halfway through the 19th century, they evolved into developing their studies at universities. Such a fact left indelible marks, which served to differentiate engineers from doctors and jurists” [3], p.155. Despite this comment which conveys the kind of social outlook that is common in Anglo-Saxon countries, there has always been a subtle separation into, at least, two different profiles, only a short time ago formalized or extended into a national framework full of nuances.

On analyzing the curriculum of schools classified as “research universities” by the Carnegie Foundation, U.S.A., (i.e., schools which are organized according to Humboldt’s concept of research university), we have found requirements such as good scientific education, reasonable humanistic education, some degree of education on a specialized technical area (organized under two themes, the major and the minor), and a wide variety of elective subjects to be chosen from. Similar situations occur in Oxford and Cambridge (U.K.), both of which have graduated administrators of the British Empire (including in engineering) based on the Humanities. This profile could be referred to as that of an “engineer with a humanistic education and a scientific base”.

Graduates from these schools achieve prominent positions (just check the well-organized yearbooks), but after the four years required for obtaining their degrees they are oriented towards preparing a PhD, which may be attenuated to an MSc or an MBA. This fact indicates that the courses themselves are not seen as terminal per se, but as stages for the furthering of education that will eventually lead to management positions or to scientific or technological research. In opposition to the type of education offered by other engineering schools, they are oriented towards preparing a leading class, albeit on technical grounds. If it is the student’s desire, more advanced technical education may be obtained in post-graduation courses. In this case, the student would be repeating the French educational system according to the 3+2 system (three years of general education and two years of education on a more specialized, although never quite technical level).

On analyzing the curriculum of British (non-university) engineering schools and a considerable number of American schools, which are not classified as research universities, a highly technical orientation with no scientific education is to be noticed: the above mentioned “technological engineer with a short education”. This kind of engineer moves straight on to jobs in the industrial sector. Later on, as a matter of prestige, he may seek complementation for his education by obtaining an MSc or an MBA, where he will study basic sciences or acquire education in management. The total amount of students who choose this path, however, is largely outnumbered by post-graduate students who have obtained their degrees in research universities. The definition for this kind of education is given as follows: “Focus on engineering practices; a project based on well-defined standards and procedures, limited use of mathematics; a considerable number of professors with a history of experience in the industry and/or close ties with the industry.” [4].

Recently in Great Britain, the British Engineering Council, an official agency created by a royal charter, has come to classify degrees according to three different types [5]:

- technician engineer (EngTech), a specialized technician, not considered a higher education degree;
- incorporated engineer (IEng), an engineer with a three-year, industry oriented education with no scientific base (mathematical modelling – understanding of theory and IT);
- chartered engineer (CEng), an engineer with a four-year education and a solid scientific base (application of appropriate Maths, Science & IT).

Yet, we must be cautious when dealing with the subtleties involved in British titles and denominations. Incorporated engineers and chartered engineers are accredited degrees, the former being obtained after a three-year course, the latter after four. After obtaining this academic base, the professional is expected to acquire at least four years of (initial) professional experience, so as then to be interviewed and have his curriculum appraised in a Final Test of Competence & Commitment, after which he/she will pass on to the final Registration stage. In fact, he/she will be interviewed every five years in order to obtain the revalidation of his Registration, at which point his/her professional development on a continuous basis will be checked. In this case he/she is automatically accredited as a European
an engineer, a situation which was created by the Fédération Européenne d’Associations Nationales d’Ingénieurs (FEANI), founded in 1951 and held in high esteem in the European milieu. This latter situation proves that the education received by the chartered engineer and the German ingénieur with a long education both point in the same direction. However, the convergence only becomes clear once each of them achieves explicit professional acknowledgement.

However, when compared to the French pretension, one difference remains both for engineers coming from a research university and for those who have received their education on a more technical basis: “engineers” in the U.S.A and in Great Britain solve given problems, as pointed out in [6]. These authors even suggest that the ABET should introduce a new criterion in its EC2000 program, leading students to “attain the ability to identify, formulate, and solve engineering problems”. In another quotation by the same authors, they suggest the creation of a “predisposition to work effectively with people who define problems differently than they do”.

Considering industrial needs, Dodridge [5] points out the need for a threefold increase in the amount of graduated incorporated engineers and chartered engineers. British statistics, nevertheless, provide consistent indication to the contrary. This trend, contrary to the labor market as seen by the academy and by government agencies, may be explained by the different levels of prestige conferred on the social roles associated to each type of engineer, as well as by the fact that those who choose the path leading to the chartered engineer gain easy access to an extended, constantly changing labor market, as it occurs in the case of the French ingénieur. The awareness of this phenomenon in the specific situation of one’s own country is shown in the knowledgeable answer given by the Lithuanian representative to one of the questions presented by the SEFI (Société Européenne pour la Formation des Ingénieurs): “it is not safe to prepare a specialist for a very concrete/specific position in the labor market, once the labor market in the country is not so stable at present and the priorities set for industrial development in Lithuania are not yet quite clear… because of the changes occurring in work conditions, and, in case of layoffs, graduates should be flexible enough to be able to adapt to new conditions” [7]. As a result, he condemns short specialized education and defends the long, more generalist education oriented towards an extended labor market, similar to that of the chartered engineers or ingénieurs.

V The Brazilian situation

Until thirty years ago, the roles assigned to engineers in Latin-America were mostly restricted to positions in equipment purchasing management or the execution of projects that were bought overseas. What was actually required from them in terms of competence involved not so much the instrumental and technical capacity acquired in the educational area, but, to a greater extent, the mastery of a specific technical terminology (not its application) and the ability of adaptation to the company. This caused the industrial sector to make no distinction between a specialized technical form of education and a superficial and simply bibliographical one, proving to be more sensitive to the social background of the applicants (which needs to be said, was generally reflected by the school of origin) [8].

Another anomalous role is that of the individual who is legally responsible for projects and operations, a characteristic of authoritarian societies where professions are conferred by the state based on legal definitions. In this case, technical qualification is irrelevant for the role, the performance of which solely requires a diploma obtained in a legally certified course and its registration in the legally compulsory corporation (the CONFEA/CREAs in Brazil).

In addition to using traditional American textbooks with a focus on “programmed instruction”, these characteristics actually indicated the education of “bachelor engineers”, a term very commonly used when criticizing the education of engineers in Brazil. Based on what has been mentioned above, the Brazilian industry milieu made no distinction between the “bachelor engineer”, who was prepared to proffer a technical discourse, and the “polytechnic engineer” or the “specialized engineer” as defined in the existing legal texts (in legal habilitation lists and/or minimum curricula).

In 1988, a brief attempt was made to offer “operational engineers” education in three-year-long courses with the possibility of completing a long education by attending two additional years in complementary courses. Since the initiative was soon to be aborted, it is not worthwhile discussing its actual or intended educational profile. The CONFEA/CREAs system refused to register these professionals and the category faced extinction in the 70s.

Nevertheless, centering on the SENAI and CEFET systems, the country has a long tradition in the education of specialized technicians. CEFET technicians usually face identity crises: after they succeed in applying for technical jobs, frustration soon sets in as they begin to question the type of education they have received. Neither are they engineers – therefore never do they reach head positions – nor do they admit repetition, a characteristic of habitual technical activities [9]. The notion of “graduate level technician” seems not to be acknowledged in Brazilian culture (or in the industrial reality). Hence, when it does exist, it is necessarily filled in by engineers who have graduated from less prominent schools.

VI A STRATEGIC CHANGE IN THE AMERICAS

A spectacular example of strategic changes in educational profiles took place in the Americas in the mid 50s of the past century: the creation of the “scientific engineering” concept. Although, at least in the U.S.A., the labor market had witnessed a certain thrust, the scientifically based technologies that were developed in the second half of the past century as well as the socio-political significance attached to the Space Race and the Cold War (the Kennedy era) constituted two major factors which resulted in the introduction of new
The same can be said in the Brazilian case, where subjects such as Physics and Mathematics were developed within the logics of these sciences, regardless of any significant integration into the professional subjects. This is one of the examples of the effect caused by the resistance presented by professors and the academic structure to profound curricular alterations: new contents are incorporated, yet unabsorbed, via new professors (of physics and mathematics, in this case) and new subjects. It needs to be said that the level of sophistication and demand regarding what is being taught has increased thanks to post-graduation courses and to the ever growing qualification of graduation course professors (in the Brazilian case, most obtained abroad) that results from government policies for faculty qualification.

When a certain reaction began in the U.S.A in the mid-eighties (laws permitting the exploitation of patents obtained with government funds), its reflection was felt in Brazil 15 years later. With the end of the Cold War in the 90s, Physics lost its hegemonic position causing new government policies to redirect the engineering curricula. We have already commented on the NSF initiatives in the U.S.A, that funded school partnerships (coalitions) for the elaboration of new curricula (in the plural) or new teaching methodologies. In Brazil, the PRODENGE, a national program (initially commanded by FINEP, a state agency), which aimed at creating thematic networks for engineering research (RECOPE subprogram) and the engineering teaching reforms (REENGE subprogram). An analysis of the American case appears in [11] and [12]. The results of the PRODENGE have been summarized in [13].

One of the motivations of these programs was the effort to establish a connection between basic research and development, in other words, between invention and innovation. In trying to create a deeper and more critical integration, the concept of industry and school clusters appeared within this context. In Brazil, the most characteristic aspect was the effort to develop product “engineering” on a national basis as a form of breaking away from the historical dependency on developed nations. It seems noteworthy to point out that social well-being still stands as the major value (now associated to new products and no longer to the basic sciences themselves.), although the motivation is geo-political: increasing national productivity levels, achieving successful integration into world markets, and, in the case of PRODENGE (in opposition to government policies of the time), reducing Brazilian technological dependency.

Another type of motivation was the hegemonic position held by market vision, where the “employability” of engineers becomes more and more dependent on their managerial competence and on their capacity to solve problems, and less on their specialized technical knowledge. The only difference is that nowadays this occurs in a globalized market: multinational education (double degrees and interchanges) and ethical outlook on a more extensive basis are qualities that have become more cited and in greater demand. A change occurs in engineers’ roles: from that of specialized technicians, with or without complementary scientific
education, they evolve into that of managers with a technological outlook, capable of acting within the market arena or developing innovations and products.

In the Brazilian case, this general orientation gained official status in the National Curricular Guidelines for Engineering Courses, homologated in 2002 by the Brazilian Ministry of Education. Engineering courses are still trying to grasp its scope and create the corresponding educational technology by choosing new educational profiles along with the corresponding curricula. More recently, the National Academy of Engineering in U.S.A. [12], proposed that a Masters Degrees should begin to refer to professional education and a Bachelors Degrees to an intermediary level. This initiative increases to 5 or 6 years the duration of engineering education, thereby fulfilling the desideratum of “preparing engineers to solve problems yet unknown and not to face given scenarios with known techniques” [12].

VII CONCLUDING REMARKS

We notice that there is a considerable difference between the sense given to the title of engineer and the social role expected from him by society in different countries, depending on their particular history and traditions. Nowadays, however, there seems to occur a convergence when defining new educational profiles, at least when it comes to defining the profile of a highly qualified engineer with a managerial vision who’s future lies in managerial positions requiring a technical base. A new role made common in post-industrial societies seemingly needs to be filled out, one in which engineers’ methodological and scientific education has become crucial.

Since they merely lose their cultural predominance, the former social roles do not disappear altogether. New engineers being introduced by the new century must be entrepreneurs, must possess the required scientific base in order to keep in pace with technological advances and foresee their function in the economy. As they will be operating within a new social model, they must assume new attitudes and demand a new type of education. All of the characterizations presented in the turn of the century and which have been discussed above seem to converge. The characteristics of this new engineer require a long education, although profiles of a quite different nature may fit into the global scheme. As examples, we have the “generalist engineers” proposed by the French Écoles Centrales, the “entrepreneurial engineers” with a scientific base proposed by PUC-Rio, or the Poli2015 proposed by the USP Polytechnic School, although the latter two have not yet resorted to all the possibilities offered by recent Brazilian legislation.

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