Engineering Education as an Area of the Scientific Knowledge

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Abstract – This paper aims at discussing Engineering Education considered as a scientific area that exists not as a simple combination of two areas that compose its denomination (Engineering and Education), but as an area that must respond to the current challenges of formation and professional practice in Engineering nowadays. With that in mind, a retrospect and an analysis about the various aspects that involve this area are presented and the main specialties that comprise it are put forward.

Index Terms - Engineering Education, Scientific Area, Engineering course

INITIAL CONSIDERATIONS

This paper is based on the studies and research by the authors having as a main source the works done together with the researchers that attend the Engineering Education Meeting, already on its XI edition, whose major organizers are professors of Engineering from the Federal University of Rio de Janeiro – UFRJ and Federal University of Juiz de Fora – UFJF [1]. A special source of reflection on that theme was the project of implementation of the graduation course (*stricto sensu*) in Engineering Education, which has been one of the main aspirations of the researchers that militate in this field of knowledge and which entails, as well, the creation of the Laboratory of Engineering Education at UFJF.

INTRODUCTION

Over the last decades, technological and organizational changes have accelerated, with impacts being felt on all sectors of society. These changes have been affecting the professional formation, as well as determining the appearance of new professional profiles and new requirements for the work in general.

The current production patterns based on concepts like quality, productivity and competitiveness, among others, determine that the new products and enterprises should be supplied or put in the market with better quality, lower costs and in a shorter time. To attend to those issues, the activities of the engineering professionals must go beyond the simple application or reproduction of scientific and technological knowledge concerning the utilization and performance of those new artifacts. These changes, for sure, have repercussion on the professional formation and qualification in engineering, especially with regard to the undergraduation courses.

In spite of the curricular guidances having made the curricular organization flexible, one notices that the majority of Engineering Schools continue to supply their courses without managing to pay proper attention to those issues. The current structuring of the engineering courses is still basically the same of the École Polytechnique, founded in France in 1795, by the initiative of Gaspard Monge and Fourcroy and which became a model for the foundation of engineering schools in several countries [2] – [3]. Since then, the curriculums have been organized, in most cases, taking into account the hierarchization and division of sciences into basic and applied of engineering or vocational.

The Engineering Schools, for the most part, continue to graduate professionals based on curriculums whose organization makes the integration among the various disciplines difficult. The student has difficulties seeing the practical relation that exists between them in the development of a project or execution of a particular enterprise. Not to mention the didactic aspects that eventually aggravate the "learning", due to teaching methodologies that take much more into account the issue of "how to teach" than of "how to learn".

The current organization of engineering courses in Brazil, by and large, arises from changes concerned with the formatation of the same which prevailed during the decade of the seventies. That model is not exclusive to the engineering schools, but to all the Higher Education system, which went through a significant reformulation in the late sixties. Such formatation for the Higher Education was practically an adaptation of the American teaching system, exasperating, as well, the division of the courses into "basic" and "vocational", with the explicitation of those in distinct cycles.

In the basic cycle of engineering, in which the disciplines of exact sciences were predominant, one would

presuppose the teaching of the basic content for all areas of engineering, the student being supposed to choose his area of preference after the accomplishment of that first cycle.

The response to this scenario may be noticed through the growing movement around "Engineering Education", as it can be evaluated by the intervention of various scholars that publish in the ABENGE magazine (Brazilian Association of Engineering Education), among others, who have been seeking to formulate proposals for engineering courses, so that they become more adequate to the present needs of professional formation, in attention to society's demands.

Such worries have also been object of study abroad, in a more intensive manner, as registered in publications like: Journal of Engineering Education – American Society for Engineering Education; The International Journal of Engineering Education – Tempus Publications (Hamburg, Germany); Journal of Professional Issues in Engineering Education and Practice - American Society of Civil Engineers.

In a general way, the majority of those studies point to a need for improvement, or even for surpassing the current model of engineering courses organization, pressuposing from a review of modalities, passing through proposals of curricular restructuring and content formatation, to the change of aspects related to pedagogic concepts and practiced teaching/learning methodologies.

On the other hand, one can notice that the developed studies in the area of Education have been more focused on the Elementary and High Schools and the interventions regarding Higher Education are predominantly punctual. Except in terms of concept and theoretical approaches, the research and scientific production concerning Higher Education, as one notices from Engineering, haven't resulted from projects, research or programs in the field of Education.

Most research activities regarding Engineering Education have occurred from initiatives of researchers in the area of Engineering that worry about the professional formation and organization of those courses. Formerly what there was of initiative in this field elapsed as complementary or assessorial, although nowadays one can see consolidated movements that owe nothing, in epistemological and methodological terms, to the remaining fields of knowledge recognized as such.

Therefore, the target of this work is to present a study on Engineering Education, viewing it as a scientific area of knowledge that has interfaces with Education and Engineering, but that doesn't constitute a result of the combination of those two areas.

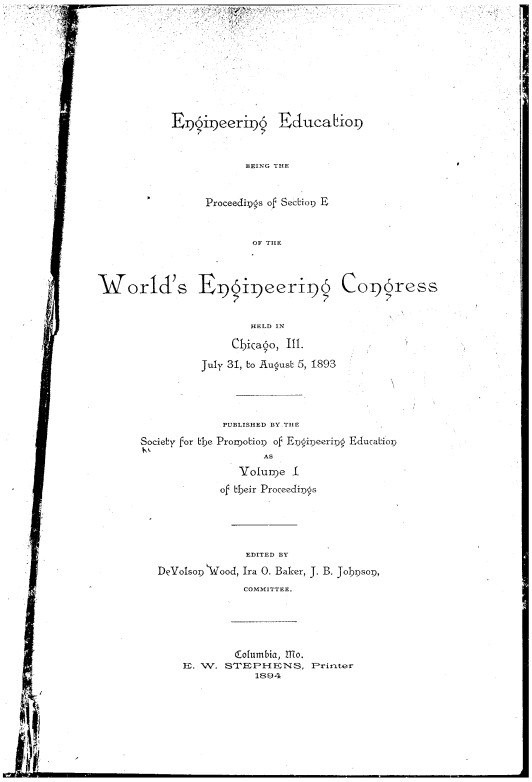
BRIEF RESTROSPECT ABOUT THE ENGINEERING EDUCATION IN BRAZIL

In Brazil, the oldest file found in the bibliography (Telles, 1994) and which presents the organization of an engineering course in a structured way is the "Letter of Law" from December 4th, 1810, by the Military Academy, which is a successor of the first engineering school in the country – Royal Academy of Artillery, Fortification and Design, founded in the city of Rio de Janeiro on December 17th, 1792. That regulation was based on what ruled the École Polytechnique of Paris (founded in 1795).

Referring to the Higher Education that he had found in Brazil in the eighties decade of the XIX century, Claude Henri Gorceix (1842-1919) – French professor founder of Escola de Minas de Ouro Preto – argued that: "Addressing memory alone paralyses the development of intelligence; one teaches the student how to discourse without mistakes, but one doesn't teach how to think or reflect". It must be underscored that, before that, in the Military Academy and later at the Central School, there were already many complaints about the existence of few practical classes, as registered in [2] – [3]. Those Gorceix's criticisms, as well as the complaints against the fact that the engineering course was little practical, crossed the centuries and reached the present days, being perfectly applicable to the engineering courses of today.

Over those last two centuries, no revolution had been registered in the organization of the courses nor in the methods and engineering teaching/learning techniques. Over the time, new means were added to aid the teaching/learning process, as a result of technological developments, such as the episcopy, the slide projector, the mechanical calculator, then the electronic one and, more recently, the informatized media (the micro-computer and the multimedia). Nevertheless, what can be seen is that those means have been used according to the same methods and techniques secularly applied, that is to say, that which was "written on the board" for the students to copy is now "projected on a screen" by means of those new tools.

In terms of events related to Engineering Education, the most ancient records found were the annals of the "World's Engineering Congress", also quoted as "International Congress of Engineering", promoted by the "Society for the Promotion of Engineering Education" and carried out from July 31st through August 5th, 1893, in the city of Chicago (Illinois/USA) ("Figure 1").



Engineering Education

BEING THE

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EDITED BY

DeVolson Wood, Ira O. Baker, J. B. Johnson,

COMMITTEE.

Columbia, Mo.
E. W. STEPHENS, Printer
1894

Source: North Carolina State University Library (NCSU)

FIGURE 1
LAYER OF THE PROCEEDINGS: 1ST INTERNATIONAL CONGRESS OF ENGINEERING EDUCATION (329 PAGES)

Those annals were found by the author in the North Carolina State University Library in the city of Raleigh (North Carolina/USA) and are known as the first sequence of events promoted by the "American Society for Engineering Education". In the quoted event, representatives from several countries were present, but only those of the major countries deserved mentioning, namely: England ("mother country"), France, Germany, Austria-Hungary, Russia and Italy.

The Society for the Promotion of Engineering Education, founded in that year of 1893, is the current American Society for Engineering Education (ASEE), which is an entity dedicated to promoting the engineering and technology development of Engineering Education.

In the proceedings of that event, one registers the preoccupation with making the learning autonomous, with active attendance in the classroom and group work as well, with the students being trained to defend their points of view. The merely expository class was already criticized and fought against.

In Brazil, there may have been other events, but what has been registered in the consulted bibliography, such as the first Congress of Engineering Education, took place from July 23rd through 25th, 1979.

LEGISLATION ABOUT REGULATION AND ASSESSMENT IN BRAZIL

The current legislation is derived from Law number 9394 from December 20th, 1996, which "establishes the directives and bases of the national education". The engineering courses must be consonant with Resolution number 11/2002 which "institutes the national curricular directives of the engineering graduation course", which, in a word, disposes of, among others:

- Principles, foundations, conditions and proceedings for engineering formation;
- Development and evaluation of pedagogic projects;
- Profile for those graduating, egressed or professional of engineering;
- Competences and general abilities for the formation in engineering;

This resolution also disposes of the fact that the course must have, among others:

- A pedagogic project;
- Synthesis and integration paperworks of expertise acquired during the course, at least one of those being an obligatory activity as a requirement for the graduation;
- Complementary activities (scientific initiation, technical visits, etc.);
- A nucleus of basic subjects, a nucleus of vocational subjects and a nucleus of specific subjects which characterize the modality;
- Basic subject nucleus with about 30% of minimum study time;
- Nucleus of vocational subjects with about 15% of minimum study time;
- Nucleus of specific subjects that is comprised of extentions and furthering of contents from the vocational subjects nucleus;
- Minimum study time of curricular professional training must reach 160 (a hundred and sixty) hours;

Another fundamental issue in the area of Engineering Education is the evaluation. In April, 2004, Law number 10.861 was passed and it "institutes the National System of Higher Education Assessment – SINAES" with the "intent to secure national process of assessment of Higher Education institutions, graduation courses and academic achievement of their students". The curricular directives and the SINAES brought about significant changes to be implemented in the Engineering graduation courses. Such changes are in the implementation phase and one still doesn't have a clear picture of the extent and consequences of the same in the courses in terms of organization and professional formation.

The present legislation, in terms of regulation and assessment, is undeniably advanced in relation to what existed previously. For the first time, directives have clearly been introduced about didactic and pedagogic aspects and about management and evaluation of courses [4]. Besides that, the demands implied in those provisions pressupose that a course, to be organized, needs to contemplate institutional and academic management and assessment, demanding treatment on sounder bases so that they are bound to succeed.

ENGINEERING EDUCATION NOWADAYS

Concerning the present scenario, the engineering courses remain to face the challenge of building a new organizational and academic model capable of meeting society's current demands. The new engineers must control a wide set of

concepts and information and must do their job in an increasingly multidisciplinar way. One notices, still, the growing amplification of the activity field of engineers in the areas of management and administration.

Those changes have demanded curricular remodeling of the engineering courses and the incorporation of new disciplines such as sociology, philosophy, psychology, communication and biology, among others. This reality begins to ask for a critical, enterprising, creative and capable engineering professional likely to give appropriate responses to the new problems that result from a transformation dynamics that has been taking place in an intensive and profound manner in all sectors.

Within that context, the engineering schools have been challenged by the need for continuously incorporating new knowledge and tools, however there is a conflict of diffficult solution: although there is consensus about the need for widening the basis of knowledge, the same is not true of the formation time. On the contrary, there is strong pressure for the reduction of the courses integralization time, based on the expectation that new educational technologies will make the courses more "efficient" or that a reorganization of the courses into curricular modules could further and consolidate a wider scientific basis and, at the same time, generalize the technological formation of the course, leaving the specialization to the professional life. Beyond value judgement, there is no question that it is a polemic and complex issue that demands deep reflection from studies and research supported by solid scientific bases.

The traditional teaching practice used in a vastly majoritarian way in the country's engineering schools is based on the concept that knowledge is spread through expository classes, laboratorial practices and its learning is checked by means of tests. This approach, consolidated in the middle of last century and which constituted an advance for the society of that time, today is not able to produce the socially demanded responses. Experiments have been made, almost always in an individual and disarticulated way, in the sense of trying to improve the "quality of engineering teaching". Although a few positive results have been achieved, one hasn't come to the formulation of alternatives for the present model, as one can notice from specialized publications and in the annals of national and international events related to the theme. Besides that, the new educational technologies haven't managed to make the courses more "efficient" neither have they met all the social demand for college formation and for work qualification and requalification.

In the international scenario, that challenge has expended efforts and substantial investments that have provided the opening of new discussion forums and institutional and cooperative enterprises between the universities, but they still haven't provided recognizably effective alternative models, although they have consolidated this as a new strategic academic field. Besides this central issue, concerning the teaching/learning model, there are others that also demand reflection, research and institutional treatment. The engineering courses present high rates of evasion and retention, even those with high demand and that recruit the best students from High School. Those and other problems due to the insufficiency of the current teaching system have already been diagnosed, as well as it has already been verified that the traditional ways of tackling them don't produce the desired effects to solve them.

Those indicators evince the exhaustion of the traditional models of teaching/learning and engineering courses organization and show the necessity to search for urgent solutions for the same. One must still consider that the challenges faced today in the management and planning of the educational system in engineering are enormous, as they encompass a series of factors that range from the subjects curricular organization, the contents and the articulations between the several disciplines, to the interdisciplinar treatment of engineering problems, the teaching/learning methods and techniques, which are, among others, elements of the formation system that currently have a high level of complexity. Additional difficulties may be noticed by professor-engineers and course coordinators who, given the need for an academic management of the courses, feel incapable of fully playing their roles, due to the lack of adequate formation.

Still concerning the future perspective of greater complexity of engineering objects and problems and the corresponding need for the cooperative addressing of those problems by professionals of diverse specialties, it is legitimate to conclude that the difficulties in the planning of the engineers' formation cannot be solved based on temporary inititiatives, such as *lato sensu* training courses, which are limited in their practical results. Not even through sporadic fomentation programs, launched by edicts that, for not being permanent, instal good perspective of results during their period of validity to soon, being interrupted, destruct the questioning and reformulating breath with which they were started.

Nowadays it is clear that those search formats for improvements or alternatives for the Engineering Education have become insufficient. The structure and process of formation for the engineer, which is known not to finish with the undergraduation time, are claiming for, at least, the same academic and scientific treatments provided to the diverse fields of scientific/technological knowledge that make up the professional basis of the engineer. In fact, when considering the strategic importance of that professional for the development, much more needs to be done based on that conceptual rationalization of the Engineering Education field.

Acknowledging the specificity of the theme and the fruitless historical relation between the academic domains of essential knowledge for Engineering Education, the necessity to recognize this field as an area of knowledge is imperative for the institutions to be able to face the challenges, that is, it is necessary for the institutions in the field of engineers' formation to effectively develop research and experiments for the collective construction of efficient proposals and models in the field of Engineering Education. That requires the systematic involvement of the teaching staff in permanent programs of research and qualification so as to meet what is today imposed as a challenge to the institutions, and the remaining alternative is the treatment and recognition

of Engineering Education as an area of knowledge on level with the others.

THE AREA OF ENGINEERING EDUCATION

In terms of actions that, in a way, contributed to raise the interest for thematic issues specifically concerned with Engineering Education, one has as near antecedent the activities resulting from the implementation of the PRODENGE/REENGEE project which took place in the second half of the nineties decade. Those actions were developed, though with delay, within the same world current of changes in Engineering Education as, for example, the actions that had developed in the United States beginning in 1990 (Engineering Education for the 21s^{t} century) which created the American Coalitions of Engineering Education, example that in Brazil translated into the Regional Coalitions created in the late nineties.

Currently taking place in the United States is the program Engineer of 2020 sponsored by the National Science Foudation (NSF – www.nsf.gov), by the SBC Foundation (AT&T – att.sbc.com), by the NEC Foundation of America and the National Academy of Engineering (NAE – www.nae.edu), which is being developed, among others, by programs of graduation in Engineering Education from American universities, which were created as a result of the quoted project Engineering Education for the 21st century.

This program intends to develop actions aiming at the quality and diversity of Engineering Education and at directing the policies and the management in the institutions of Engineering Education. For that, this program intends, among others: To identify significant actions for Engineering Education; To organize studies and develop long term strategies for the future of Engineering Education; To recommend specific policies and strategies to subsidize government agencies and academic administrations.

One of those examples is the University of Virginia Tech that has a department of Engineering Education with 15 professors working in the undergraduation and postgraduation of Engineering Education [5], which provides disciplines like: History, theory and practice of Engineering; Contemporary actions in Engineering Education; Use of virtual reality and visualization tools for Engineering Education and in sciences; Preparation for the teaching profession in Engineering; Communication in Engineering and in sciences; Theory, practice and pedagogy, among others.

By and large, the field of knowledge of Engineering Education refers to the insertion universe of Higher Education in Engineering (undergraduation, postgraduation, research and extension) and its related areas, beginning with a systemic approach encompassing the management of educational systems in all its aspects, people's formation (teaching and technical administrative staff), the didactic pedagogic organization, particularly the political pedagogic projects of the courses, the methodologies and the means of teaching/learning. This area seeks to consolidate those issues, as well as aims at presenting the concrete results of the activities developed, viable alternatives of courses organization for the perfecting of the teaching profession, field in which the professor is already intensively involved without finding appropriate structure for the furthering of his or her reflections and investigations.

This area, indeed, comes to create the institutional space of Engineering Education on sound scientific and academic bases which, so far, have been incipient in the institutions that count on unselfish researchers in the area and inexistent in the vast majority of the IES in the country. There is nowadays, however, a fertile field for the fast dissemination of this area resulting from the initiatives that have been implemented beginning with the current legislation concerned with Higher Education, particularly the curricular directives of the Engineering course (Res. CNE/CES 11/2002) which present a series of innovations regarding the previous legislation. The SINAES (National System of Higher Education Assessment), as well, which institucionalizes the assessment from a series of categories, is another open space to the works that demand studies and research and that have as an essential basis in Engineering, the area of Engineering Education.

The activities developed within that area may effectively:

- Contribute to the transformation of the teaching activity into an effectual research and teaching/learning process endowned with foundations, methods, tecniques and scientific means;
- Contribute to the transformation of the management and academic evaluation activity into a professional process based on processes, methods, techniques and scientific means;
- Permanently form and qualify the teaching staff and researchers as capable of making proposals of course organization and continued education in Engineering;
- Do research and make experiments for the collective construction of new institutional teaching/learning models for the courses of Engineering and related areas;

In terms of specialties within that area, one can identify at least two trends nowadays essential for the organization of formation systems in Engineering:

- Management and assessment of systems in Engineering Education, in which studies and research would be done concerning the management and evaluation of educational systems in Engineering and its courses, such as: management of systems, quality, information technology and organizational strategy, among others, aiming at the formulation of improvement proposals for the current systems based on the SINAES (National System of Higher Education Assessment), as well as proposing new assessment models developed on scientific and academic bases. Included on this line are the studies on the teaching/learning assessment.
- Methods, means and distance education, in which studies and research would be carried out about methods and current educational means of learning/teaching aiming at improving and adapting them to Engineering, as well as developing new

methods and means for the teaching/learning process in Engineering. The studies and research on methods and means that support the extra-curricular activities stand out on that line, according to the present curricular directives for the Engineering course (Res CNE/CES 11/2002). And still, given the present relevance and importance of distance education (EAD), one can do studies and research targeting the study of the viability of Engineering courses creation with the aid of resources of that technology.

One of the fundamental problems that would be solved within that area is the formation of professionals capable of performing the role of managers, coordinators and professors in the Engineering formation educational systems.

Until recently most of the Engineering teaching staff were professionals that played a role in the job market and practiced teaching, many times as a "hobby" and out of having an altruistic spirit, among others. Teaching professional experience and academic entitlement were not the most important to start a professional teaching career. There was a belief that if an engineer were professionally successful, he would automatically be a good professor. Nowadays, that belief has turned into entitlement, one thinks that if an engineer has a doctor's or a master's degree and if he is a recognized researcher, then he will be a good professor. For the vast majority of engineer-professors without didactic-pedagogic formation, teaching would be linked to inactivity, to being gifted. It would suffice, according to the present conception then, to know "how to convey knowledge". To evaluate would be to prepare and apply a test and to write up the result.

Today it is clear that it does not suffice for the engineering professor to master the scientific and technical knowledge of subjects, or the functioning of the means available to "supply" such subjects. It is necessary that the teaching professional knows and applies structured and consistent teaching/learning methods and techniques that pressupose the appropriation of knowledge, without which he or she will not manage to contribute to the formation of professionals capable of continuously updating themselves and meeting society's demands.

FINAL CONSIDERATIONS

The authors hope to have brought about a reflection on Engineering Education that can contribute for the same to be recognized as an area of knowledge, which actually exists, but not yet by rights and which is not a simple combination of two areas that compose its denomination (Education and Engineering), but as an area that comes in the current of the need for responding to the present challenges of Engineering formation.

If facilities, teaching staff and the curriculum would previously suffice for a course to be implemented, today the professional formation claims for much more than that. The complexity that involves the organization of a course nowadays circumscribing the management and institutional and academic assessment, the political pedagogic project of the course, the teaching/learning methods and means, the knowledge contextualization and integration activities, among others, make up a whole that claims for a systemic approach and that is confined within that area of knowledge called Engineering Education.

Only through the recognition of Engineering Education as a field of knowledge by rights will it be possible to develop continuous lines of research and the creation of *stricto sensu* graduation courses as they already exist in developed countries. The decision about this recognition may determine the future of the technological development in the country, sector which has least produced in Brazil over the last years, mainly with regard to the transformation of the results of basic research into technological products, which takes in essence the articulation between the several fields of knowledge that comprise the universe of Engineering, and this articulation is one of the main purposes of Engineering Education.

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