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The Academic Criteria for "Dottore Magistrale in Ingegneria (Laurea Magistrale)"

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Abstract

After the Bologna Declaration, in Italy, as in other European countries, successive modifications of our university engineering programmes are introduced. Two independent degrees in series have been introduced: a 3-year Laurea and a 2-year Laurea Magistrale; the first to supply students with adequate understanding of scientific methods and contents, not necessarily oriented to the acquisition of professional competences; the second devoted to advanced level education for high quality activities in specific areas. At the same time, a certain number of measures, introduced by the government, have had positive impact on the overall effectiveness of the education process. Of course, some aspects should be updated; uncertainties concern the profile of Laurea engineers and the qualitative level of Laurea Magistrale engineers.

Introduction

Engineering has a critical importance in the economical and social development of our countries. Engineering creativity impacts on the industrial process, on infrastructural systems, new solutions, new services and the safe conditions of people.

So, the Institutions that work around the formation of engineers and their qualification - in primis the Schools of Engineering - have the great responsibility to provide graduates with guaranteed qualified competences to practice the Engineering profession. In this context I would like to express my appreciation to the generous work done by the Consiglio Nazionale degli Ingegneri (CNI) and to the efforts for the organization of this conference.

This paper will focus mainly on Laurea Magistrale, on the goals that it plans to achieve, on the organization of the course of study, and on those problematic aspects, commonly shared, for which however, it's difficult to find a solution.

In order to understand this, it is necessary to recollect the deep changes of the last decades, starting from an overview of the organization of Engineering studies before the Bologna Process, to understand how it impacted on Engineering education in Italy and to analyze the present situation. Since we are dealing with Laurea Magistrale, the second and last step of a 5-year course, it is obvious to draw a comparison with the old Laurea, a very hard 5-year programme, that for many years has been the only kind of programme offered by Italian Engineering Faculties. To give a brief outline of the evolution of the organization of Engineering studies I will make reference to the paper that Alfredo Squarzoni presented during the latest CLAIU Conference in Bruxelles [A. Squarzoni, CLAIU EU, Bruxelles, 2010], establishing a continuity with his analysis of the Italian situation.

The 5-year Laurea and 3-year Diploma

Until the late eighties, Italian Engineering Faculties offered only one kind of programmes: the 5-year Laurea. Laurea programmes were "theory-oriented" programmes, which provided students with a broad basic education both in scientific and engineering disciplines, through a typically deductive approach.

The organization of the courses was centralized: programmes, qualification and curricula were mostly established by law. There were 15 Laurea programmes, subdivided into three sectors - civil, industrial and information - and the list of the modules consisted of about 28 annual modules each one of at least 80-100 hours, with the total amount of teaching activity over the five years amounting to at least to 3000 hours.

Graduates of the Laurea programmes were highly appreciated by the job market for their methodological approach to problem solving, while criticism regarded a shortage of knowledge of non-technical implications of engineering practice, such as industrial and commercial implications and project management. Some evident weak points were the high number of drop-outs (60-70%) and the excessive duration of the studies (the average was 7-8 years). Finally, in many jobs, engineers did not fully exploit the competence acquired at university.

In the late eighties, when the demand for engineers from the job market increased and the faculties were not able to produce enough engineering graduates, Confindustria and others, required the introduction of 3-year application-oriented programmes, to be delivered in parallel with the Laurea programmes. The Diploma programmes, introduced in 1990, were meant to

qualify graduates to deal with short-term technical and industrial problems, therefore the study of scientific and engineering disciplines was mainly connected to their applied aspects. The teaching approach was typically inductive and the teaching activity developed over three years amounted at least to 2100 hours, with at least 500 devoted to practical laboratory and training. Diploma graduates could continue their studies in a Laurea programme and in case of strict relation between them (i.e. the same name), graduates in the Diploma programme were generally admitted to the 3rd year of the Laurea programme and the number of annual modules to be attended by a graduate could not be greater than 18 out of the 28 foreseen by the Laurea with the possibility to use freely the acquired credits. However, Diploma courses were mostly taught separately because of the different educational objectives of the two qualifications.
As a matter of fact, Diploma programmes never took off, only 15% of Engineering students chose a Diploma programme, the other 85% were enrolled in Laurea programmes. From this point of view it has almost failed.

The (3+2) year course : Laurea and Laurea Specialistica

After the Bologna Declaration in 1999, Italy was one of the first European countries to embrace in full the Bologna indications. The (3+2) model was implemented in Italy in 2001 in all fields of studies and its explicit aim was first of all to harmonise our Higher Education system with the European model established in the Bologna Declaration but also, among other goals, to improve the effectiveness of university education, through the reduction of drop-outs and a better correspondence between the formal duration of studies and the time actually taken to graduate. The new model foresaw a 3-year Laurea programme, followed by 2-year more to obtain Laurea Specialistica programmes, in series, with the following objectives:

1 3-year Laurea programmes: provided students with an adequate mastering of general scientific methods and contents and specific professional skills;
2 5-year (3+2) Laurea Specialistica programmes: provided students with advanced level education for high quality activities in specific areas.

The legislator's aim was that the first cycle graduates would take up most of the job positions occupied by the old 5-year Laurea graduates. It's important to underline that there has been a long and tiring debate about the introduction of the (3+2) system and at the end the system in series has been a political choice. The Conference of the Deans of Italian Engineering Faculties

(CoPI) had warned, with little success, of the possibility that such a model could compromise the possibility of accomplishing the qualitative educational level required by second cycle programmes. However, even those who had supported the model of the two degrees in parallel, which would have needed much more resources than the available ones, were confident, on the basis of the previous Diploma experience, that just few students would choose the short course, considered for such a reason, an inferior class degree.

The Laurea programmes belonged to 4 classes : Building, Civil and Environmental, Industrial and Information Engineering, while the classes of Laurea Specialistica programmes belonged to a higher number of classes: Building Engineering, Civil Engineering, Environmental Engineering, Mechanical Engineering, Naval Engineering, Aerospace Engineering, Automation Engineering, Electrical Engineering, Energetic and Nuclear Engineering, Chemical Engineering, Biomedical Engineering, Telecommunication Engineering, Electronic Engineering, Management Engineering, Computer Engineering, Mathematical-Physical Model for Engineering, Material Science and Engineering.

I am not going to mention in details all the qualifying objectives of Laurea and Laurea Specialistica programmes but only some of them in order to highlight the differences between the two programmes:

1. Qualifying Educational Objectives of Laurea programmes in Engineering
   - appropriate knowledge and understanding of the methodological-operative aspects of mathematics and of the other basic sciences and ability to apply such knowledge for the interpretation and description of engineering problems;
   - appropriate knowledge and understanding of the methodological-operative aspects of engineering sciences, both in general and in-depth for the disciplines characterising each programme, and ability to identify, formulate and solve problems by using up-to-date methods, techniques and instruments;
   - ability to use techniques and tools to design components, systems, processes;
   - ability to conduct experiments as well as to analyse and interpret data;
2 Qualifying Educational Objectives of Laurea Specialistica Programmes in Engineering
   - adequate knowledge and understanding of the theoretical-scientific aspects of mathematics and other basic sciences and capacity to apply them for the interpretation and description of complex and interdisciplinary engineering problems;

- knowledge and understanding of the theoretical-scientific aspects of engineering sciences , both in general and in-depth for the disciplines characterising each programme, and ability to identify, formulate and solve complex or interdisciplinary problems, also in an innovative way;
- ability to devise , plan, design and manage complex and/or innovative systems, processes, services;
- ability to design and manage highly complex experiments;

In conclusion, knowledge and understanding of context and transferable skills given by Laurea Specialistica programmes are more advanced than those acquired in the Laurea programme.
These learning objectives and minimum contents of curricula were a consequence of the legal validity of the degrees awarded by Italian Universities, that constitute an essential requisite for the employment in the public sector and an essential pre-requisite for the "State Exam", which qualifies for the practice of the Engineering profession.
The first cycle programmes were designed to guarantee both the acquisition of professional skills and the mastering of scientific methods necessary to continue the studies in the Laurea Specialistica programmes. They were more "practice-oriented" than "theory-oriented" but in the end, due to the necessity not to compromise an adequate mastering of general scientific methods and contents, they were not so practice-oriented as required by the job market.
The second cycle programmes had to guarantee a qualitative level comparable with the old 5-year Laurea, they had to be "theory-oriented", favouring the study in depth of the theoretical-scientific aspects of the disciplines already studied in the first cycle programmes but with attention to their applied aspects.
Unfortunately this idea was never applied successfully due to the difficulty of reconciling a "practice-oriented" course with a "theory-oriented" one, and to the difficulty of plugging the gaps in basic education accumulated in the first cycle studies. In the attempt not to compromise the possibility of pursuing studies in the second cycle, first cycle programmes offered in the last year or in the last six months two different paths: one job oriented and the other oriented to the continuation of the studies to bring back to life the idea of the courses in parallel (the so-called "Y model") also if only for one year or half a year.
Despite the fact that the aim of the reform was to meet the majority of the job market needs with the first cycle graduates, most of the first cycle graduates (about 80%) have chosen to continue their studies in the Laurea Specialistica programmes.

This is due to the fact that the first cycle degree has always been seen as an "inferior class" degree compared with the "superior class degree" represented by the Laurea Specialistica degree. On the other hand the representatives of the job market, who strongly supported the implementation of this first cycle degree, actually never showed much interest in these types of professional figures.

The objective of a limited number of selected first cycle graduates enrolled in the Laurea Specialistica programmes would have required the definition of strict admission criteria but it's difficult to make drastic choices when the funds allocated by the ministry depend on the total amount of enrolled students.

Therefore the implementation of the Bologna Process has not positively influenced the level of education of second cycle graduates with respect to the graduates of the old 5-year Laurea. Its main weak point has certainly been the difficulty in first cycle programmes of reconciling two conflicting needs, i.e. guaranteeing adequate grasp of general scientific methods and contents necessary to continue the studies in the second cycle programmes and adequate professional skills directly employable in the job market.

An updating of (3+2) model : the Decree DM 270

At the end of 2004 the Minister for University issued the decree DM270 which revised the DM509/1999. The new decree revises the objectives of the first cycle Laurea programmes and establishes that it has to have the aim *of supplying student with adequate mastering of scientific methods and contents, even when oriented to the acquisition of specific professional competences.*

Therefore, with this decree, the necessity to acquire in the first cycle programme professional skills has taken second place while the necessity to strengthen the knowledge of basic disciplines is underlined. Moreover, a clear distinguish between curriculum oriented to the prosecution of studies and curriculum preparing students for the job market is highly recommended and a clear separation between first cycle and second cycle programmes is introduced also in order to encourage flexibility in educational paths and student mobility among universities. The Laurea Specialistica became the Laurea Magistrale, our model is now made up of the Laurea and the Laurea Magistrale, an independent degree with respect to the Laurea.

This reform became operative in the academic year 2008/2009 and the decrees that implemented it provided for a set of measures aimed at reducing the number of programmes offered by the Italian University system by introducing:

- transparency requirements;
- requirements for quality assurance of educational processes;
- requirements for infrastructural and faculty quantity and qualification facilities, which must be available to the programme, in relation to the scientific/learning areas involved;
- dimensional requirements (maximum and minimum number of students that each programme can effectively sustain)

Educational objectives of Laurea Magistrale

The objectives of Laurea Magistrale is to train professional figures with a broad spectrum of knowledge and skills able to work on complex design projects, in the management and operation of complex systems, and within R&D departments. The 2-year curriculum is structured to give students an autonomous capacity for analysis of complex engineering problems in different areas, preparing them for both domestic and international contexts, whether in the working world or in research and development. Graduates will have the capacity to autonomously develop both standard and innovative projects in terms of system product and process, working both independently and in multidisciplinary teams and with responsibility for coordination.

The formation is based on courses that reinforce the engineering background gained during the 3-year Laurea degree, but that also introduce new elements that will allow graduates to fill positions of responsibility. Students are offered [illegible]ers of both theoretical and practical teaching units so that they can address engineering problems characterized by a high level of complexity. The contents of these units are strongly correlated, not only with shared engineering practice, but with innovative results achieved in research.

The broadly transversal training allows graduates to adapt quickly to different professional requirements, even in sectors other than that of their degree course. They will be prepared both to interact effectively with experts from different sectors, and to continuously update their professional expertise.

For example in Laurea Magistrale in Mechanical Engineering the goals of the programme are to

provide:
- in-depth study of mechanical subjects; a high level of knowledge of the technical-scientific problems of various sectors underlying applications and innovations in engineering (materials, functional and structural design methods, energy, production systems, numerical modeling);
- in-depth knowledge and solid expertise in one of the areas in which mechanical engineers traditionally operate (production, design, automation, plant engineering, propulsion of vehicles, transport).

On the other hand, the Laurea Magistrale in Civil Engineering is designed to train a professional figure with a broad spectrum of knowledge and skills in the design, implementation, management, surveying, testing and maintenance of buildings (civil and industrial), major public works (bridges, dams, tunnels) and infrastructure (roads and transport, systems for water collection, distribution and treatment).

Positive results and open problems of DM 270 model

In the last few years there have been some changes in the effectiveness of our system, first of all in the number of graduates. It is difficult to say if there is a direct connection between this fact and the reform itself.

Probably, besides the reform, there is a set of measures introduced by the government – more transparency, efficiency indicators, rewards connected with the duration of the studies etc. – that have influenced university strategies. It has been ascertained that 10 years after the reform the number of graduates have increased, the duration of the studies have decreased with the consequence that students graduate younger, the number of students regularly in course and the attendance at the lectures have increased and the relationship with the outside world has also encouraged experiences abroad.

Mainly a strongly monitored situation and an increase in the regularity of the studies are noted. These considerations are even more realistic if referred to Laurea Magistrale. Actually there is still a percentage of drop-outs but it is moderate, and it concerns above all those students who have entered the working world and who have not either interest or energy to continue the 2nd cycle-course anymore. In any case they have a Laurea degree.

High dropout rates continue to exist during Laurea which is a delicate problem and difficult to solve since it affects the students starting from the first year: these drop-outs are due to the

scarce preparation of the students. For these students it should be necessary to arrange other opportunities and easier technical course.

Certainly the DM270, which has clearly separated the two levels and has cancelled the necessity of a technical-professional training for the Laurea , this on one hand has increased the number of students who pursue their studies, and on the other hand has suggested changes that take advantage of the fact that the majority of students continue their studies. Therefore in many cases the (3+2) degrees resemble ever more a 5 year-length programme. This has induced some to try a return to a one-cycle degree, foreseeing in particular cases two paths: a 5-year one-cycle course in parallel with the traditional (3+2) course.

Frequent critical reviews of our university programmes concern the need to pay

- more attention to systems rather than to their specific components, as a result of a certain fragmentation of the studies.
- more emphasis on the non-direct engineering aspects, such as economical and management matters, communication, importance of team working.

As far as professional qualifications are concerned, we understand that there should be a clear differentiation between the educational programme that trains professional engineers involved with advanced technologies and design, and the education programme that trains professional engineers involved in project management and working teams .

A 5-year engineer is expected to acquire large competences in design and management of complex projects in various contexts, on refined modelling of engineering systems, processes and phenomena, should be able to deal with multi-disciplinary problems, to design, realize and manage sustainable engineering systems and processes. But it is difficult that at the end of Laurea Magistrale, that is only 2 years after the Laurea, the student can make such an important leap, obtaining this increase in the competences.

One of the main concerns is the decrease of the students' ability in fundamental matters – mathematics, physics – and the need for more bridging studies, mainly in innovative fields. Other important points are possible modifications driven by the needs of industry and international compatibility.

In Italy a large part of the revenue of public universities comes from the government, while only a small part comes from industry. Actually this last part is quite different from one university to another and is usually greater in the north. In view of the small budget of private companies, their involvement is consequently small.

Another open problem concerns the professional qualification: the situation is governed by a law, but a diffused feeling is that 3-year degree provides skills for access to employment as technical engineer, while 5-year degree provides skills for access to employment as professional engineer. It seems that the trend is to require 5-year of university schools to reach a qualification level necessary to become a professional engineer. But also this point needs more in-depth analysis.

Conclusions

The Bologna Declaration required us to introduce a large modifications in our Engineering course: the old 5-years Laurea is divided in two degrees 3-years Laurea and (3+2)-years Laurea Specialistica, in series but connected. Laurea programmes provide students with an adequate mastering of general scientific methods and contents and specific professional skills; Laurea Specialistica programmes provide students with advanced level education for high quality activities in specific areas.

The first cycle programmes were designed to guarantee both the acquisition of professional skills and the mastering of scientific methods necessary to continue the studies in the Laurea Specialistica programmes. They were more "practice-oriented" than "theory-oriented" but in the end, due to necessary compromises, they were not so practice-oriented as required by the job market. A weak point of this reform has certainly been the difficulty in first cycle programmes of reconciling two conflicting needs, i.e. to guarantee adequate mastering of general scientific methods and contents necessary to carry on the studies in the second cycle programmes and adequate professional skills promptly usable in the job market.

An updating modification of the same structure (3+2) degrees leads to revising the goals of the 3-year Laurea that has to focus on adequate mastering of scientific methods and contents, even when oriented to the acquisition of specific professional competences. Moreover, the two degrees are now completely independent, thus permitting student mobility.

Notwithstanding these improvements and positive results obtained in the overall efficiency of the new system, some aspects of uncertainties and dissatisfaction remain; this will inevitably mean that some adjustments could follow.