

Engineering Education – Theoretical vs. Applied Approach

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Abstract: This paper deals with the offer of education programmes as entry route for the engineering profession. We argue that Today it is well established that Society needs two main levels and two main profiles for engineering programmes. Levels should be related to levels 6 and 7 of the European Qualifications Framework for Lifelong Learning, recommended by the European Union. Profiles should range between more theoretically oriented and more applications oriented programmes. Tuned with the concept of lifelong learning, the structure should include bridging programmes that should allow students to choose more freely their education paths. All in all, we should not forget the keywords of Today's paradigm of European development – mobility, cooperation and competition.

Introduction

The issue of *Theoretical* vs. *Applied* approaches, or more appropriately that of two existing profiles of educational programmes as entry routes for the professional activities in engineering, a more theoretically oriented vs. a more applications oriented profile, is on the table, as food for discussion, for many years.

The issues and the questions are – which levels of knowledge, competences and skills in engineering, are required by the Society, by industry in particular, to provide the required contribution of engineering for increasing the well being of Humanity? Do we need different profiles of education for such purposes?

The problem is in fact that the answers to the underlying questions are not limited to technical, scientific and professional issues. There are political and social issues also at stake.

In the first section of this paper an overview will be given of the conceptual frameworks for analysis of engineering education.

This will be followed by a section where questions concerning existing and possible levels and profiles of engineering programmes are discussed.

1. Qualifications frameworks – meta-frameworks and sectoral frameworks

Before proceeding with the specific analysis of the main issues, it is relevant to revisit the developments concerning reference frameworks adopted at European level, aiming at academic and professional recognition.

The key documents are (i) the Qualifications Framework for the construction of the European Higher Education Area, directly related to the Bologna Process (QF-EHEA,

2005); (ii) the European Qualifications Framework for Lifelong Learning, developed within the European Union (EQF-LLL, 2008); (iii) The EU Directive on Recognition of Professional Qualifications (Directive, 2005); and (iv) the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes (EUR-ACE, 2006).

Meta Qualifications Frameworks and related high level descriptors.

These characterize high level groups of qualifications. Existing frameworks differ in background and objectives, employing different sets of descriptors, or grouping such descriptors in different clusters of outcomes.

At European level, two main frameworks are currently in place:

- (i) The Qualifications Framework for the construction of the European Higher Education Area (QF-EHEA, 2005), approved by the 46 signatory countries (at the time) of the Bologna Process.

The QF-EHEA focus on the post-secondary education system and adopts the well known Dublin Descriptors that identify four cycles of higher education (three main cycles plus short cycles within or linked to First Cycles).

Table 1 identifies the five clusters of descriptor that form the structure of the Dublin Descriptors.

Table 1 - Clustering of qualifications descriptors in different frameworks

Bologna, QF-EHEA	EU, EQF-LLL	EUR-ACE
A. Knowledge and understanding	1. Knowledge	I. Knowledge and understanding
B. Applying knowledge and understanding	2. Skills	II. Engineering analysis
C. Making Judgments	3. Competences	III. Engineering design
D. Communications skills		IV. Investigations
E. Learning skills		V. Engineering practice
		VI. Transferable skills

- (ii) The European Qualifications Framework for Lifelong Learning (EQF-LLL, 2008), a Recommendation of the European Parliament and of the Council, approved on April 23, 2008.

The EQF-LLL aims at describing the entire education system, recommending eight levels of qualification, each identified by descriptors grouped in the three main clusters of outcomes equally presented in Table 1.

The Directive on Recognition of Professional Qualifications is not a Framework in the through sense of the term, but it has the force of law in the space of the European Union

(Directive, 2005) and as such it should be included in this group of meta-references for recognition of qualifications.

(iii) The Directive aims at regulating this major issue of qualifications recognition in the EU space and focus on the post-secondary system, though not including the doctorate level.

The Directive makes a fundamental differentiation between those professions where some common platform of activities and related basic training are identified (the case of professions in the area of health and of architecture) and the other professions where no common platform of activity and requirements are identified. The former professions are subject of the Directive Annexes, whereas the latter fall within the general system for the recognition of qualifications. For this general system, where Engineering is included, Article 11 defines five levels of qualification, of which three levels are associated to post-secondary education.

Unfortunately, the current legal version of the Directive is still linked, in the old way, to 'years' of work, which means that it is largely out of touch with all trends of concepts for recognition of professional qualifications. It is expected that the review currently in progress changes such limitation.

In any case, the Directive has now been implemented in the EU space. The Database of regulated professions in the EU Member States, Iceland, Norway, Liechtenstein and Switzerland is now available for consultation (EU, 2008). In spite of the limitations pointed out, considering the close relation of the Directive and the QF discussed, it constitutes a major instrument to enforce the whole concept for recognition purposes.

Sectoral Frameworks – EUR-ACE

Sectoral frameworks are concerned with specific discipline descriptors and ideally result from wide transnational co-operation and agreements between stakeholders, namely higher education institutions and professional associations. Sectoral frameworks should naturally relate to and be identified within the wide descriptors of the meta frameworks, but they quite clearly are expected to be more detailed in the descriptions. Depending on the sector of knowledge, they may be further subdivided in sub-sectors characterized by specific domain descriptors, including, if applicable, the identification of professional activities for which the candidates are to be prepared. Engineering is a good example of a sector that requires specific domain descriptors, related to the different specialties.

Speaking of the wide Engineering Sector, we can identify a number of relevant initiatives (see Feyo de Azevedo, 2009), again driven by different objectives, hence with somewhat different structures. Here we single out EUR-ACE:

(iv) The EUR-ACE framework for accreditation of engineering programmes (EUR-ACE, 2006; Augusti, 2007a, 2007b, 2009), which to a large extent was influenced by the results of the TUNING project (TUNING, 2000), aims at constituting a reference framework to ensure the suitability of programmes to serve as entry routes to the engineering profession.

The EUR-ACE system includes guidelines for the criteria and requirements for programme assessment that at least consider the following items: (1) Needs, objectives and outcomes; (2) Educational Process; (3) Resources and Partnerships; (4) Assessment of the educational process; and (5) The management system.

In what concerns curriculum requirements and objectives, EUR-ACE is built around the six Programme Outcomes identified in Table 1. It is quite clearly a major proposal both for Europe and in a global context.

How do meta and sectoral frameworks fit together?

This is of course a major question with a simple answer – though different in nature, yes, they fit together (Feyo de Azevedo, 2009), as synthesized in Table 2, where the relations between the levels of qualifications adopted in the different frameworks and in the Directive are outlined.

Globally the different levels proposed are coherent with and fit well in the overall qualifications structure adopted both by the QF-EHEA and the EQF-LLL, and also by EUR-ACE in the engineering area.

The objectives of the EQF-LLL are different, wider in scope, from the QF-EHEA. Yet, the proposal caused some reaction of the Countries signatories of the Bologna Process not pertaining to the EU. Possibly for such reason the Recommendation carefully signals the existing relation with the QF-EHEA in what concerns post-secondary education.

Table 2 - Relating levels of qualifications in different frameworks

Bologna, QF-EHEA	EU, EQF-LLL	EUR-ACE	EU Directive 2005/36
Short Cycles (ShC)	Level 5 (L5)		Art. 11 c)
First Cycles (FC)	Level 6 (L6)	First Cycles (FC)	Art. 11 d)
Second Cycles (SC)	Level 7 (L7)	Second Cycles (SC)	Art. 11 e)
Third Cycles (TC)	Level 8 (L8)		

2. Programmes for engineering education – levels and profiles.

The issue here is that of the organisation of engineering programmes in direct relation to the organization of the engineering profession. Two words about the latter:

In the period that preceded the approval of the Directive, that is mainly the years of 2003, 2004 and 2005 (first semester), an intense discussion took place at European level where two main views were discussed (i) the line that considered that engineering education should be seen in terms of a common platform, with limited requirements of formal education (3 years); and (ii) the line that considered that there were two main levels of education, leading to complementary, but different levels of knowledge, competences and skills of their graduates.

The latter view prevailed clearly and as a result the Directive did not include engineering in the group of disciplines with a single platform, a group that remains confined, as already pointed out in this text, to the health disciplines and architecture.

It must be mentioned that within this prevailing line of thought, there is not a single vision of education and the profession across the European countries - not only levels of education, but also profiles are at stake.

Higher Education for the Engineering Profession

Following the preceding comments, in this section we revisit and discuss the diversity of organization of studies adopted in the European countries, linking such offer of education to the requirements of the engineering profession.

In engineering, a scientific but also technical domain where a binary system of education makes sense and exists in several countries, the discussion has been significant, in recent years, about levels and profiles of required education, namely on the type of First Degrees that should be awarded by Higher Education Institutions. Such discussion took mainly place within the FEANI¹ and also within the CLAIU², between 2002 and 2005, prior to the approval of the Directive for Recognition of Professional Qualifications.

Though not all Countries share or adopt the same structures and concepts in their professional organization, we take the view that two levels of engineering education and two main types of degree profiles are relevant to the profession.

¹ FEANI - Fédération Européenne d'Associations Nationales d'Ingénieurs, www.feani.org

² CLAIU - Council of Association of Long Cycle Engineers of a University or higher School of Engineering of the European Union, www.claiu.org

Levels

Levels are widely recognized and accepted, mainly after the publication of the QF-EHEA (2005), the Directive (2005) and the EQF-LLL (2008).

The two levels of education primarily identified as “higher education for the professions” are the First and Second Cycles of the QF-EHEA that correspond to Levels 6 and 7 of the EQF-LLL (Table 2).

The levels are directly related to the expected qualifications of the professionals and to the expected engineering activity, both evaluated in direct relation to relevant technical, scientific and social aspects, such as having: (i) social responsibility (namely signing of projects, of which those in structural engineering are possibly the most relevant); (ii) recognized capacity to tackle large, complex problems; (iii) capacity to adapt to new jobs of high complexity and responsibility; (iv) capacity for effective activity in the production line; and, not the least, (v) the right attitude to use knowledge and skills in a given situation.

Programme outcomes should be evaluated against such criteria, thinking of the programme as entry route for the profession at one of the recognized levels.

Profiles

Profiles have much to do with the prevailing concepts in a country about the professional requirements for the engineering activity. This of course will be related to the mission of the Institutions, which in turn should be related to the background of Teaching Staff.

Our views are that there should be an offer of programmes for engineering education ranging between more theoretically oriented and more applications oriented profiles. The set of recommendations of the VDI—Society for Chemical and Process Engineering (VDI-GVC, 2008) represent an excellent example of this type of distinction in the offer of engineering programmes.

Fig. 1 presents the concept of a degree system designed for maximizing employability potential of First Cycle graduates. This is the concept that originally presided to the QF-EHEA. Within this view, First Cycles should contain essentially all the basic desired learning outcomes relevant to the professions, these being enlarged and matured from cycle to cycle.

Differences in outcomes for First and Second Cycle Degrees are associated to or related with scope, depth and breadth, which is in line with the suggested progression along the degree system depicted in Fig. 1.

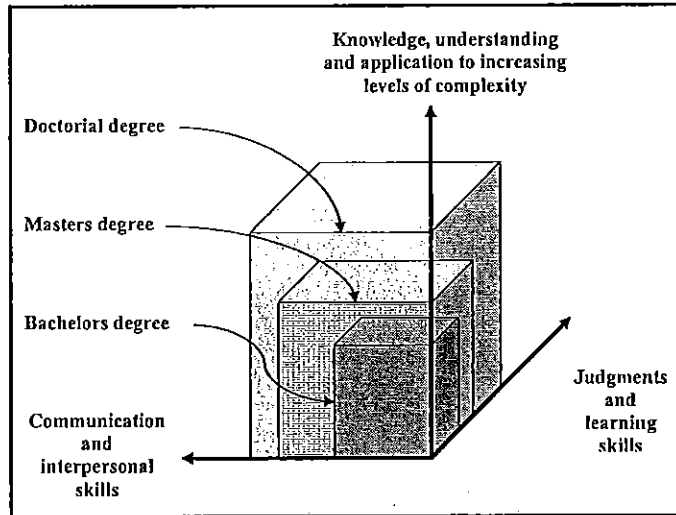


Figure 1 - A concept for progression of Knowledge, Competences and Skills along the different cycles of the degree system.

The relevant perspective that we share is represented in Fig. 2, stressing out the two trajectories of education.

The Figure depicts the case raised, from the very beginning of the Bologna reforms, by Research Universities, namely those that are part of CESAER³. They have argued that First Cycles of the more theoretically oriented profiles that characterize the education offer of Research Universities would not, or would not necessarily, lead to qualifications recognized as entry routes to the profession.

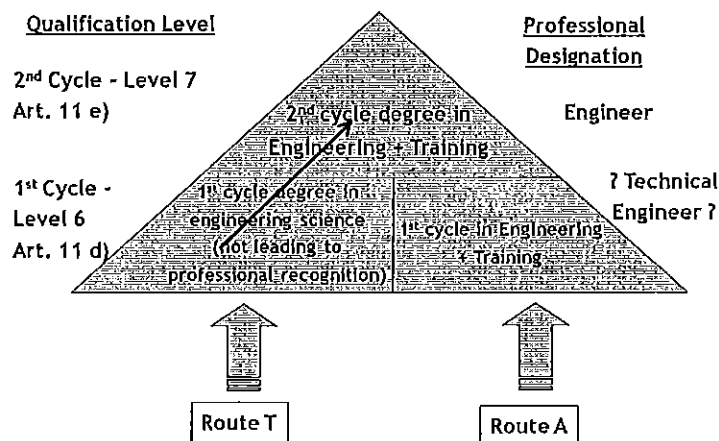


Figure 2 – Offer of Engineering Education – 2 levels, 2 profiles – Route T: more theoretically oriented; Route A: more applications oriented

³ CESAER - the Conference of European Schools for Advanced Engineering Education and Research, www.cesaer.org

Another form of the same view, projecting different information, is presented in Fig. 3. Here we include the possibility of having, a professional master, possibly shorter than the academic master, though eventually at the same level 7 of the EQF-LLL scale.

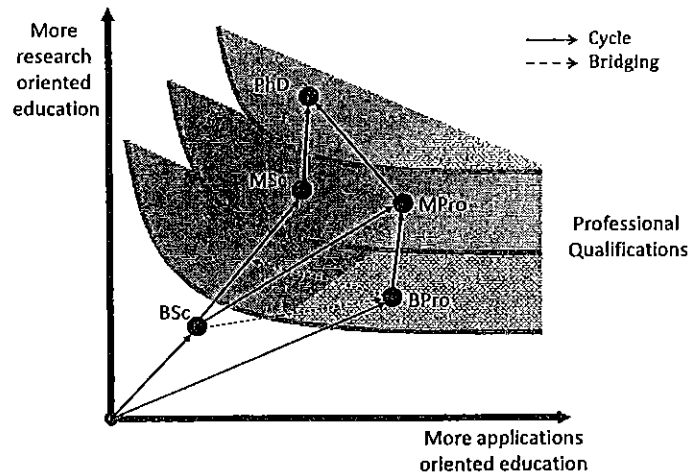


Figure 3 – A concept for offer of education and related professional qualifications in Engineering, including two recognized profiles of master programmes (inspired in: J.D. Woerner, U. Darmstadt, President CESAER, presented in the CESAER GA Meeting, Lisbon, 2005)

3. Synthesis and concluding remarks

A number of relevant issues should be made and left clear:

- (i) In the engineering profession, qualifications for a significant number of activities require accumulated long training at higher education level. In most countries this means the equivalent to 300 ECTS, but it is known that this is not the generalized situation.
- (ii) An important issue of Today's life is whether such education should be achieved through long cycle degrees, or if it can be achieved through accumulated two-cycle studies. The question of the type of offer is more and more a political issue, of educational policies, and in fact virtually all countries are adopting the two-cycle system, independently of the qualifications associated to First Cycle degrees.
- (iii) What is also relevant is that the education systems include some form of communication between profiles that may lead to conversion or continuation of studies - that is to flexible study paths. This type of flexible scheme of education that we favor is depicted in Fig. 4.

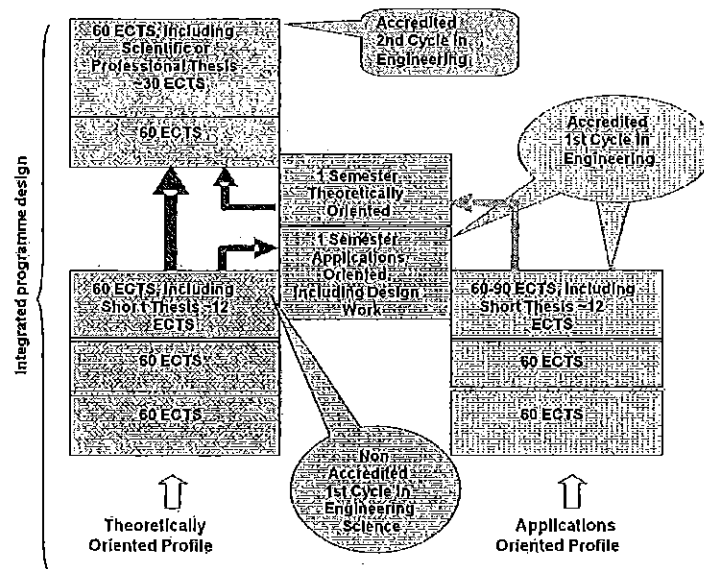


Figure 4 – Offer of Engineering Education – 2 levels, 2 profiles - with bridging programmes

(iv) From the point of view of a framework for evaluating the programmes as entry routes for the profession, it is clear that there should be only one set of standards for First Cycle degrees and one set of standards for Second Cycle degrees, against which the degree programmes should be evaluated. This is indeed the concept adopted in the EUR-ACE system.

(v) Still with EUR-ACE, though the programme outcomes and accreditation criteria outlined in the *EURACE Framework Standards* have been designed to be applied to the accreditation of the two main cycles defined in the Bologna Declaration, the use of programme outcomes makes these *Standards* applicable also to the accreditation of programmes leading directly to a degree equivalent to a Second Cycle Degree, conventionally termed “Integrated Programmes”,

(vi) Last, but not least, we should not forget the keywords of Today’s paradigm of European development – mobility, cooperation and competition. Mutual trust is key for achieving mobility and cooperation, indeed the major goals of the Bologna Process. To create such trust it is necessary to build transparent and readable academic curricula and professional qualifications, recognised and accepted by all partners and stakeholders.

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