THE REFORMS OF THE BOLOGNA PROCESS, RECOGNITION OF CHEMICAL ENGINEERING QUALIFICATIONS

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Abstract: Two key political, academic and economical issues in the prevailing scenario of the contemporaneous global World are those of transnational co-operation and mobility of students and professionals. Co-operation and mobility require academic and professional recognition. Such recognition requires TRUST. Trust requires transparency and readability of academic curricula and professional qualifications. Such is achieved through transparent qualifications frameworks and quality assurance procedures recognised and accepted by all partners and stakeholders. Qualifications frameworks may be seen at three major levels of descriptors, viz. – (i) High level descriptor of competences, of a general nature, describing essentially qualifications degrees; (ii) Sectoral descriptors grouped in scientific and technological areas with direct relations to the different professions; and (iii) Contents descriptors, characterizing main or core curricula contents and methods. The understanding by all stakeholders of academic degrees and related specific knowledge, competences and skills of their graduates is essential for promoting this current paradigm of 'coopetition' in the World. In this context, an immense reform is taking place in Europe, under the codename Bologna Process, involving some 16 million students and well over 5600 institutions of 46 countries. In these notes and in the lecture I shall: (i) introduce the main issues of the Bologna Process; (ii) discuss the development of qualifications frameworks at the three levels identified; and (iii) discuss some specific implications of the Bologna Process in changing methods and curricula in the chemical engineering area, having in mind the recognition of qualifications for the profession.

Keywords: Recognition, qualifications frameworks, paradigms of chemical engineering education, Bologna Process,

1. QUALIFICATIONS FRAMEWORKS, CORNERSTONES FOR QUALIFICATIONS RECOGNITION

1.1 Key issues in the Global World

Two key political, academic and economical issues in the prevailing scenario of the contemporaneous global World are those of transnational co-operation and mobility of students and professionals. With the historical background of progress in science and technology, of societal and political changes that took place on the last quarter of the 20th Century, an immense reform is taking place in Europe, under the codename Bologna Process[1]. The commitment is the creation of the European Higher Education Area, an essential step for developing a competitive economy based on a knowledge society. The Bologna Process should thus be seen on a dual environment of related and complementary, but different, academic and political 'expected outcomes': (i) the restructuring of the offer of higher

[1] Full information concerning the Bologna Process is compiled and available in the site of the Bologna Follow-up Group (BFUG) Secretariat, at http://www.ond.vlaanderen.be/hogeronderwijs/bologna/

education, leading to a more transparent and attractive offer, in a global context, nearer to the needs and interests of Society; and (ii) an evolution of teaching/learning paradigms - adapted to the concepts and perspectives of the modern society and to the available technical tools, projecting education to more adult phases of life

1.2 An open wide view of Qualifications Frameworks

Qualifications Frameworks based on Learning Outcomes represent a cornerstone of the reforms proposed within the Bologna Process - they play a major role in basically all main structural areas of the reform: (i) in developing degree systems and study programmes at higher education institutions; (ii) in the recognition of qualifications, by all stakeholders; and (iii) as a pre-requirement, in the implementation of Quality Assurance systems.

A Qualifications Framework (QF) expresses the expected learning outcomes for a given qualification, that is expresses what a learner is expected to know, understand and be able to do after successful completion of a process of learning. For such wide purpose, an open wide view of the concept of QF should be adopted. QF unfold or are made of three to four sets of descriptors related to and characterized by different levels of detail, Viz-:

Meta Qualifications Frameworks and related high level descriptors. These characterize high level groups of qualifications. They are generally developed at institutional level of governments and stakeholders. They may differ in background and objectives, and as such different frameworks may arise, employing different sets of descriptors, or grouping such descriptors in different clusters.

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 all the 46 countries that are part of the Bologna Process ;
(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.
(iii) Additionally, though not being a Framework in the through sense of the concept, a major document, the Directive for Recognition of Professional Qualifications was approved and has the force of law in the space of the European Union (Directive, 2005), that aims at regulating this major issue of qualifications recognition in the EU space.

<u>*Sectoral Frameworks.*</u> They are concerned with specific discipline descriptors and ideally result from wide transnational cooperation and agreements between stakeholders, namely higher education institutions and professional associations. Sectoral frameworks should naturally relate and be identified within the wide descriptors of the meta frameworks, but they quite clearly are more detailed in the descriptions. Depending on the sector of knowledge, they may be further subdivided in sub-sectors characterized by specific descriptor, including, if applicable, the identification of professional activities for which the candidates are to be prepared. In the Engineering area, we can identify a number of relevant initiatives, again driven by different objectives, hence with somewhat different structures:

(i) The EUR-ACE framework for accreditation of engineering programmes (EUR-ACE, 2006);
(ii) The TUNING methodology (TUNING, 2000), that, as written by the its coordinators, aims at contributing to the elaboration of a framework of comparable and compatible qualifications in each of the (potential) signatory countries of the Bologna process, which should be described in terms of workload, level, learning outcomes, competences and profile;
(iii) The ABET (Accreditation Board for Engineering and Technology) criteria for accrediting of Engineering Programmes (ABET, 2009);
(iv) The CDIO (Conceive-Design-Implement-Operate Real World) initiative (CDIO, 2002), a framework for engineering education.

Descriptors at syllabus (contents) level - core curricula. – Significant work is taking place in Europe, at this lower, but relevant level, namely through the activity of Education Working Parties, or through the initiative of higher education institutions. In the specific field of Chemical Engineering two initiatives deserve mention:

(i) The work of the Working Party on Education of the European Federation of Chemical Engineering which led to Recommendations for Chemical Engineering Education in a Bologna Two Cycle Degree System (EFCE, 2005). Such recommendations cover *Learning Outcomes and How to Achieve the Learning Outcomes*, for both First and Second Cycle degrees. The core curriculum proposed covers about two thirds of the total, leaving space for significant modifications and innovations.

(ii) The CHEMPASS Project (Gagneur, 2009), an European project involving 13 Higher Education Institutions that aims at promoting mobility and attractiveness of European Chemical Engineering Higher Education though a thorough analysis of contents and methods, and through the development of tools for competence evaluation.

1.3 Comparison of Qualifications Frameworks

In this paper the analysis will be limited to the European meta frameworks and to the one more directly related to the profession in Europe (the EUR-ACE accreditation system). Table 1 presents the main relations between the qualifications of the different frameworks, highlighting those more directly related to the engineering profession:

(i) The Bologna QF-EHEA Framework assumes three main levels of qualification, with an additional level (short cycles within or linked to the first cycles).

(ii) The Qualifications Framework for Lifelong Learning (EQF-LLL) assumes eight levels of qualifications, of which four at upper-secondary level.

(iii) At European level, significant discussion took place between 2002 and 2005, about levels and profiles of education in engineering, prior to the approval of the Directive for Professional Recognition, It is today accepted that there are two main levels for engineering education as far as the requirements for the profession are of concern. This is recognised in the Directive for Professional Qualifications and in the EUR-ACE accreditation framework.

Table 1 – 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)		

Table 2 puts in evidence the differences of approaches in the development of the different frameworks. This raises immediately the question of studying the possible relations or differences between the proposals.

To illustrate such type of study, Table 3 presents the descriptors approved for the three frameworks that are under analysis, corresponding to the second cycles of education (level 7 of the EQF-LLL Framework). Fig. 1 is constructed from the analysis of descriptors presented in the Table and puts in evidence that it is possible to relate the different descriptors adopted. As expected and perceivable the descriptors for the sectoral framework (EUR-ACE) are significantly more detailed than those of the meta frameworks.

Table 2 – 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 Judgements	3. Competences	III. Engineering design
D. Communications skills		IV. Investigations
E. Learning skills		V. Engineering practice
		VI. Transferable skills

Table 3 – Comparison of descriptors*
QF-EHEA Second Cycles, EQF-LLL - Level 7 and EUR-ACE Second Cycles

Bologna, QF-EHEA, Second Cycles	EU, EQF-LLL, Level 7	EUR-ACE, Second Cycles
SC-A. Have demonstrated knowledge and understanding that is founded upon and extends and/or enhances that typically associated with the first cycle, and that provides a basis or opportunity for originality in developing and/or applying ideas, often within a research context; **SC-B.** Can apply their knowledge and understanding, and problem solving abilities in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study; **SC-C.** Have the ability to integrate knowledge and handle complexity, and formulate judgments with incomplete or limited information, but that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgments; **SC-D.** Can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non specialist audiences clearly and unambiguously; **SC-E.** Have the learning skills to allow them to continue to study in a manner that may be largely self-directed or autonomous.	**L7.1.1.** Highly specialized knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research; **L7.1.2.** Critical awareness of knowledge issues in a field and at the interface between different fields. **L7.2.** Specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields. **L7.3.1.** Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; **L7.3.2.** Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams;	**SC-I.1.** An in-depth knowledge and understanding of the principles of their branch of engineering; **SC-I.2.** A critical awareness of the forefront of their branch. **SC-II.1.** The ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications; **SC-II.2.** The ability to formulate and solve problems in new and emerging areas of their specialization; **SC-II.3.** The ability to use their knowledge and understanding to conceptualize engineering models, systems and processes; **SC-II.4.** The ability to apply innovative methods in problem solving. **SC-III.1.** An ability to use their knowledge and understanding to design solutions to unfamiliar problems, possibly involving other disciplines; **SC-III.2.** An ability to use creativity to develop new and original ideas and methods; **SC-III.3.** An ability to use their engineering judgment to work with complexity, technical uncertainty and incomplete information. **SC-IV.1.** The ability to identify, locate and obtain required data; **SC-IV.2.** The ability to design and conduct analytic, modelling and experimental investigations; **SC-IV.3.** The ability to critically evaluate data and draw conclusions; **SC-IV.4.** The ability to investigate the application of new and emerging technologies in their branch of engineering. **SC-V.1.** The ability to integrate knowledge from different branches, and handle complexity; **SC-SC-V.2.** A comprehensive understanding of applicable techniques and methods, and of their limitations; **SC-V.3.** A knowledge of the non-technical implications of engineering practice. **SC-VI.1.** Fulfill all the Transferable Skill requirements of a First Cycle graduate at the more demanding level of Second Cycle; **SC-VI.2.** Function effectively as leader of a team that may be composed of different disciplines and levels; **SC-VI.3.** Work and communicate effectively in national and international contexts.

* See tables 1 and 2 for nomenclature

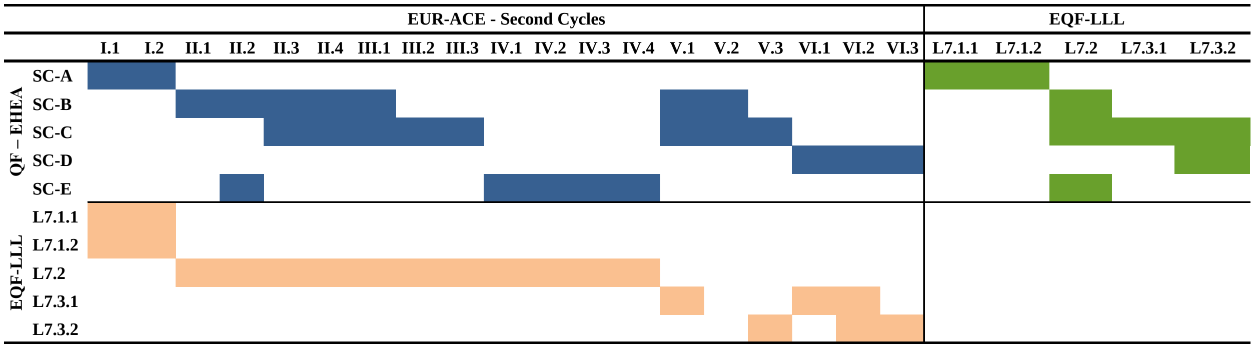

Fig. 1 – Relation between framework descriptors for Second Cycle degrees (EQF-LLL - Level 7)

In short, at European level there seems to exist a stabilised degree structure for engineering education. First and second cycle degrees, with more vocational or more theoretical oriented profiles are generally well described in terms of descriptors and expected learning outcomes. Rather than qualification levels, what is currently at stake is more and more contents and methods: (i) diverse profiles on offer; (ii) flexible paths for learning; (iii) bringing the student to the centre of the learning exercise; (iv) paying more attention to the development of personal and interpersonal skills; (v) bringing the curricula nearer to the practice of the profession.

2. FIRST AND SECOND CYCLE DEGREES IN CHEMICAL ENGINEERING

Over the years the domains of chemical engineering have been enlarged. Chemical engineering, now in a *latus sensus*, encompasses a wide set of disciplines from the classical process engineering to biotechnology, environment engineering, industrial chemistry, process systems engineering, material sciences and product engineering. A reasonable degree of diversity in chemical education is desirable. This continued enlargement of the role of chemical engineers, together with new demands and requirements from the society, with the changing time- and space-scale of technical developments, the change in working practices and together with the dominant economic factors affecting company organisation, raises major questions concerning the need for new directions of chemical engineering education.

It is clear that there is not ‘a single’ structure for a curriculum. Independently of questions of European accreditation, which will very shortly be raised in the rapidly expanding European Space, the fact is that it seems clear that no core curriculum should be imposed (by what authority?) on existing programmes, but guidelines coming out of a consensus should serve for countries seeking to develop their training programmes, having in mind that they have to meet the reference qualification framework accepted.

The more interesting academic issues have to do with changes in the degree structure, in contents and in methods, in line with the reforms in progress. These have been the subject of publications by scientists, professional engineers and associations (Villadsen, 1997; Gillett, 2001; Molzhan and Wittstock, 2002; Molzhan, 2003; NRC, 2003; Cussler, 2005, EFCE, 2005; Feyo de Azevedo, 2007).

In a significant number of European countries we face the challenge of adapting both structures and contents (leave the methods aside for the moment). Several organizations have been investing efforts for finding adequate solutions to these complex problems, particularly on the identification of a reference framework for qualifications for competence recognition. The VDI-Society for Chemical and Process Engineering approved a recommendation for the development of consecutive Bachelor-Master degrees both for ‘more applications oriented’ and for ‘more research oriented’ profiles (VDI-GVC, 2008). It is based on the EUR-ACE Framework and characterizes – (i) professional profiles and aims for the courses; (ii) qualifications for admissions; (iii) structure of the degree course, including core curricula; (iv) fields of studies; and (v) industrial placements. It represents a remarkable example on changes that promote recognition of qualifications.

There must be an understanding that it is essential that Academia and Industry, both in the European Space and in a wider context, co-operate offering each other aided-value, by accepting students for training (the Industry), by jointly designing pilot case studies, by providing theoretical background through courses (the Academia).

Some speak of a shift towards the third paradigm. There are not yet enough documents to make this shift of mindset completely clear or as clear as what we have discussed about Unit Operations and Chemical Engineering Science in the XX Century. Prospectively, for sure that in 2020 such shift will be crystal clear. In any case, if this is not (yet) a paradigm shift, it is at least an extension of the concepts of the second paradigm that, as fifty years ago, will help in pushing the frontiers of chemical engineering beyond its present limits.

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