Field-Specific Quality Assurance and Qualification Frameworks: Effects on Engineering Education

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Abstract

"General" and "Field-specific" Quality Assurance procedures, although sharing many of their "technical" instruments (self evaluation reports, peer reviews, benchmarks vs. reference points, etc.), aim at rather different directions. The motivation behind "field-specific" initiatives are critically presented in this paper. They are strictly correlated with Qualification Frameworks, that, while preserving the autonomy of the HE Institutions in defining their teaching offer, define common and transparent employability objectives for the benefit of students, graduates and all other stakeholders. However, "while learning outcomes have been generically defined for the degree structure", it is now necessary "to further develop descriptors for subject specific knowledge, skills and competences. ... leaving still plenty of freedom for programme diversity"[1]. Qualification Frameworks and field-specific Quality Assurance lead naturally to "pre-professional accreditation", that can be given an international value by "European Quality Labels": examples in Engineering (EUR-ACE) and Chemistry (Eurobachelor; Euromaster) are explicitly quoted in the paper, together with other initiatives in the Engineering field.

Keywords: Engineering education, accreditation, qualifications, frameworks, quality assurance, accreditation standards, learning outcomes, field-specific approaches, Bologna process, European Higher Education Area (EHEA).

1. Introduction: The Bologna Process, Qualifications Frameworks and Quality Assurance

In March 2010 the first decade of the "Bologna Process" was celebrated by a Ministerial "Anniversary Conference", marking a milestone in a deep reform of the European systems of higher education, that aims at fostering mobility and cooperation within Europe and creating more transparent and attractive conditions for third countries to cooperate with European Universities, without intending to establish any "uniformity" of the varied picture of European Higher Education (HE).

The reform of the structure is thus well on its way. The reform of the substance (developing readable curricula in a lifelong learning context and developing methods that make use of modern tools and meet the expectations and motivations of young people) is about to start. To a large extent we can say that the main goal of the second decade of the Bologna reform will be about bringing "Bologna" into practice.

It should be understood that promoting mobility and co-operation, the essential objectives for constructing the EHEA, requires TRUST and that for such trust to grow it is necessary to build transparent and readable academic curricula and professional qualifications. This is achieved through transparent Qualifications Frameworks (QF) and Quality Assurance procedures (QA), recognised and accepted by all partners and stakeholders.

This paper deals with QF and QA, issues that are intrinsically connected between themselves and to the concept of Learning Outcomes (LO): indeed, QF based on LO 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 QA systems.

It is to be underlined that QA systems should include clear and measurable objectives and standards: therefore, there cannot be any quality assurance without a qualifications framework. The understanding by all stakeholders of academic degrees and related specific knowledge, competences and skills of their graduates is essential for both internal and external evaluation and for recognition. This means that we have to develop and implement field-specific strategies and methodologies for QA that must be supported by related sectoral descriptors of qualifications: this paper will deal with such issue.

2. What is meant by "Accreditation"

Let us recall the definition given in the EUR-ACE Framework Standards [2][3]: "Accreditation of an engineering educational programme is the primary result of a process used to ensure the suitability of that programme as the entry route to the engineering profession." Clearly, the word "accreditation" is thus related to a field-specific approach in QA of higher education, in which the aims and contents of the educational programmes are specified, as opposed to a "general" QA approach in which essentially the quality of the teaching/learning process is assessed.

The quoted definition, written for engineering but extendable to other professions by replacing the word "engineering", combines assurance of "academic

[1] The acronyms used in this paper are defined the first time they appear.

quality" with professional relevance. Therefore, it can neither be simply qualified as "academic accreditation", nor, on the other hand, as "professional accreditation", because "academic education" may be not sufficient to be accredited for a profession (e.g., in several countries to be qualified as "engineer" a graduate of an accredited programme must fulfil further, more or less formalized "professional training" requirements, fixed by professional, not academic, organizations). Hence, in order to avoid confusions, "accreditation", defined in this way, can be referred to as "pre-professional accreditation".
Note also that in many countries the word "accreditation" (or a similar-sounding one) has a "legal" value and is reserved to the use of governmental (or para-governmental) authorities. In these cases, different terms can be and are being used to indicate what in this paper is referred to as "pre-professional accreditation" (or simply "accreditation").

3. General vs. Field-Specific Quality Assurance

Procedures for QA are increasingly accepted, if not required, in education systems throughout the World, in particular for higher education. In Europe, the reference QA document are the "European Standards and Guidelines for Quality Assurance in Higher Education" or "ESG" [4], officially adopted by the 2005 Bologna Ministers' Conference. The ESG fix common European standards for internal and external quality assurance and for external quality assurance agencies, leaving to each provider of higher education (in the following, indicated as "Higher Education Institution" or HEI) "the primary responsibility for the quality of their provision and its assurance". The ESG require that each HEI develops and publishes "explicit intended learning outcomes" of each provided programme, and pays "careful attention to curriculum and programme design and content". Also, "student assessment procedures are expected to be designed to measure the achievement of the intended learning outcomes and other programme objectives...".
The ESG refer to the "Qualification Frameworks for the European Higher Education Area" (QF-EHEA) developed within the Bologna Process [5]: this, and the parallel "European Qualifications Framework for Lifelong Learning" (EQF-LLL) [6] are meta Qualifications Frameworks that identify levels of qualifications, employing general LO descriptors: they do not specify nor refer or quote specific subject areas.
Although the ESG and in general QA practices have done and are doing a great deal to improve the European HE systems (and the same is true on the global scale) the risk is unavoidable that these, that can be defined as "general" QA procedures, lead to paying more attention to the "educational process" than to the "content" and "job relevance" of the education. That's why "field-specific" approaches to QA, based on learning outcomes (LO) defined for more or less broad subject areas, are becoming recognized as relevant and essential, as confirmed by the following examples:

i) In [1] we can read: "...the relationship between qualifications frameworks and quality assurance is crucial. Work needs to be continued over the next few years, at national and institutional as well as at European and regional level, to improve the links and interaction between the work done on qualifications frameworks and on quality assurance, involving a broad range of relevant stakeholders... While learning outcomes have been generically defined for the degree structure [through] the 'Dublin descriptors', the key point is to further develop descriptors for subject specific knowledge, skills and competences. Since the start of the Bologna Process, higher education institutions and their academics have taken up the challenge to develop international descriptors and reference points for a growing number of subject areas. Initiatives in this direction ... are welcomed and need further encouragement; ... [it is true that] the establishment of too detailed subject specific descriptors could hinder the development of interdisciplinarity... however, shared subject descriptors are only to be seen as indicative for a kind of core curriculum, leaving still plenty of freedom for programme diversity. Common reference points could also be developed for an entire sector, which might lead to the definition of sectoral descriptors and the establishment of sectoral qualifications frameworks".
ii) A field-specific definition of the Learning Outcomes (LO) is supported by the final Communiqué of the latest Bologna Process Ministers' Conference [7], where it reads: "We reassert the importance of the teaching mission of higher education institutions and the necessity for ongoing curricular reform geared toward the development of learning outcomes... Academics, in close cooperation with student and employer representatives, will continue to develop learning outcomes and international reference points for a growing number of subject areas...".
iii) The relevance of field-specific approaches in QA has been the object of a recent Conference organized by the "Fachakkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik" (ASIIN) and jointly hosted by a number of subject-specific networks [8] .
iv) The series of "TecnoTN Fora", organized by the "Archipelago of Thematic Networks in the fields of Sciences and Technology" [9], stands as another example of positive collaborations and exchanges of experience within and between subject-specific Networks and Associations.
v) A "Joint Statement", signed by the European Network for Accreditation of Engineering Education (ENAEE), the European Chemistry Thematic Network Association (ECTNA), the European Informatics Project (EURO-INF) and the World Federation of Medical Education (WFME) [10], was presented to the 2007 London "Bologna Process" Ministerial Conference.

Through these initiatives, a *de-facto* European Network of Disciplinary Accreditation Organizations is growing, formed by an encompassing alliance of stakeholders, and is developing both several European Competence Profiles at disciplinary level and pan-European sets of Learning Outcomes as entry route to several specific professions (engineering, chemistry, informatics, geology,...).

These sets of specific learning outcomes (LO) defined for more or less broad subject areas have a number of characteristics and objectives in common: they intend to

- be widely applicable and inclusive, enabling eligibility of a wide range of possible approaches to higher education;
- handle the diversity of content of degree programmes;
- be relevant for academic study programmes leading to a First or to a Second Cycle Degree;
- define qualification as entry routes to the profession;
- facilitate in particular accreditation of trans-national joint- and double-degree programmes.

Hence these LOs, applied in combination with the ESG, should lead to "pre-professional accreditation", as defined in Section 2, and Mutual Recognition Agreements for academic and/or professional purposes.

Field-specific and "general" quality assurance approaches share most of their QA "technical" instruments and procedures: self evaluation reports, peer reviews, benchmarks vs. reference points, etc. The choice should never be "either - or", but of how to best combine the two approaches in order to limit the burden placed on the organisation and its members and optimize the results. Being both approaches relevant, it is however clear that field-specific QA approaches accentuate the need for aligning the goals of educational programmes with the expectations of the relevant stakeholders, in order to be comparable and ensure their relevance for the labour market, and underline that higher education institutions, while in principle autonomous, are nevertheless accountable to their constituents, which includes an obligation to demonstrate the relevance of their output. Thus, field-specific QA systems give credibility and concreteness to the whole "Bologna"/EHEA system. For the countries of the European Union, this link to the relevant social and economical issue of employability is further stressed and strengthened by the "The Directive for Recognition of Professional Qualifications" approved by the European Council and the Parliament in September 2005 [11].

In line with these developments, the European Commission is supporting since 2006 the establishment of "European quality labels" in selected subject areas: two very recent EC documents quote the "quality labels" in Engineering ("EUR-ACE") and in Chemistry ("Eurobachelor" and "Euromaster") as examples of good practices of QA in HE [12][13].

The development of sectoral frameworks and subject specific LO has still a long way to go. It should be recognised that existing frameworks and related descriptors suffer from a number of shortcomings, e.g.:

- The formulation of LO are prone to internal and external political power games and the attempt to situate one´s own education or educational system as favourably as possible in the national and/or international context.
- No system exists as yet to measure and compare reliably HE learning outcomes across national boundaries, while in the field of secondary education there are instruments like the PISA study. Indeed, the very ambitious AHELO (Assessment of Higher Education Learning Outcomes) initiative launched on the global scale by the OECD Directorate for Education is stuck by financial difficulties, after a preliminary report was published in May 2009 [14][15].
- In spite of all the rhetoric on LOs, most Mutual Recognition Agreements rely on input criteria and/or on procedural similarities;
- The engagement of employers has not reached a satisfactory level.

Some suggestions/recommendations can be formulated in order to overcome these shortcomings [16]:

- Learning Outcomes/Competence Profiles could be developed internationally (on the continental or global scale) and brought to each others' attention, in order to learn from best practice while respecting cultural diversity;
- Development of international/joint degree programmes;
- Development of joint accreditation procedures for trans-national joint degree programs;
- Development of measurable cross-national outcomes - institutionalization of international peer groups which visit institutions and programs in several countries at the same time to cross-examine the output of study programs;
- Intensification of stakeholder involvement and cooperation between the different quality assurance/ accreditation structures and between HEIs and QA-Agencies: involvement of the Business Community is a crucial asset for this aim.

4. Meta Qualifications Frameworks

As it should be clear from the previous Section, Qualifications Frameworks (QF) unfold and are developed at three main levels of descriptors, related to and characterized by different levels of detail, viz. (i) meta frameworks; (ii) sectoral frameworks; and (iii) branch level descriptors.

Meta frameworks include high level descriptors of competences, of a general nature, describing global qualifications associated to degrees. They are generally developed at institutional level of governments and stakeholders and to a large extent represent the basis for the 'legal crust'. 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 meta frameworks are currently in place, as already hinted:

(i) The Qualifications Framework for the construction of the European Higher Education Area (QF-EHEA) [5], approved in 2005 by all countries of the Bologna Process (currently, 47), that focuses on post-secondary education, identifying four cycles of higher education (three main cycles plus short cycles within or linked to First Cycles).

(ii) The European Qualifications Framework for Lifelong Learning (EQF-LLL), a 2008 Recommendation of the European Parliament and of the Council, with effect on the European Union (EU) countries [6]. 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. The objectives of the EQF-LLL are thus different, wider in scope, from the QF-EHEA: yet, it caused some reactions of the countries included in the Bologna Process but not in the EU. To avoid these reactions, the Recommendation carefully signals the existing relation with the QF-EHEA in what concerns post-secondary education.

Besides the quoted two meta frameworks, there exists the "Directive on Recognition of Professional Qualifications" [11], although not a Framework in the full sense of the term: it has force of law within of the European Union (while no such "European laws" can exist in the field of education, that according to the European Treaties is outside the EU competences). 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. It makes a fundamental differentiation between those professions where some common platform of activities and required basic training are identified (the case of professions in the area of health and of architecture, that were up to 2005 the object of "special" Directives) 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, in which Engineering is included, Article 11 defines five levels of qualification, of which three levels are associated to post-secondary education. These levels 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 (see Section 5). A specific "Engineering Platform" is currently under discussion by initiative of professional associations from a number of countries.

5. Sectoral Frameworks

"Sectoral Frameworks" are concerned with specific discipline descriptors, grouped in scientific and technological areas, with direct relation to the different professions, and mostly directed to support quality assurance and recognition systems. Descriptors at all levels are all relevant for a truly effective QA system, but "Sectoral frameworks" are the most significant in the development of QA: to a large extent, Sectoral Frameworks represent "Bologna" in actual practice.

Sectoral Frameworks ideally result from wide transnational cooperation and agreements between stakeholders, namely HEIs and professional associations. They should naturally relate and be identified within the wide descriptors of the meta frameworks, but they quite clearly are more detailed in the descriptions.

A major concerted effort towards subject area frameworks has been the Tuning Project [17], aimed 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". In its first phases (2000 - 2004), the Tuning project dealt with 9 subject areas (Business, Chemistry, Earth Sciences, Education, European Studies, History, Mathematics, Nursing and Physics).

The engineering area, for its nature, with its several branches and its different profiles (either more theoretically or more vocationally oriented), has been the ground for a variety of sectoral frameworks, some active, some remaining at the stage of projects or proposals:

(i) The EUR-ACE Framework for accreditation of engineering programmes [2][3], a reference framework aimed at ensuring the suitability of programmes to serve as entry routes to the engineering profession. The EUR-ACE Framework distinguish between "First Cycle" and "Second Cycle" degrees (as in the European QF) and includes guidelines for the criteria and requirements for programme assessment, indicating that at least the following items should be considered: (1) Needs, objectives and outcomes; (2) Educational Process; (3) Resources and Partnerships; (4) Assessment of the educational process; and (5) Management system. The EUR-ACE Framework and the related de-centralized accreditation system has been described in several papers [18][19][20], including two presented at previous GCEE [21][22].

In [23] the relation and compatibility of the EUR-ACE Framework outcomes with QH-EHEA and EQF-LLL have been demonstrated, together with a comparative synthesis of descriptors for the different outcomes and for the two relevant qualifications levels. The relevance of the EUR-ACE Framework both for Europe and in a global context has been confirmed by the fact that it has been taken, together with the ABET criteria (cf. (ii) below) as the basis for the First Cycle Programme Learning Outcomes in Engineering agreed in the framework of the AHELO feasibility study (see (vi) below).

(ii) The ABET criteria for accrediting Engineering Programmes [24]. ABET (Accreditation Board for Engineering and Technology) is a federation of 29 professional and technical societies of the United States of America, that runs a well established system

that includes nine criteria for the accreditation of engineering programmes. It should be noted that ABET has been developed within a context where, essentially, the First Cycle (Bachelor) degree is the natural entry route to the profession.

At present, there is a lively debate about introducing in the USA some sort of Second Cycle (Master) degree: it is therefore of utmost and urgent interest to relate on the global scale the engineering recognition and accreditation systems of the Americas, Oceania and Asia with EUR-ACE and the European QF. Work in this direction has already started thanks to an agreement of collaboration between ENAEE and the International Engineering Alliance, that coordinates three "Accords" for the mutual recognition of degrees (Washington, Sydney and Dublin, respectively at the level of "Professional Engineers", "Engineering Technologists" and "Engineering Technicians") and three "Professional Mobility Fora" ("APEC Engineer agreement", "Engineers Mobility Forum", "Engineering Technologist Mobility Forum") [25].

(iii) Within the mentioned TUNING methodology, the proposals of the "Engineering Synergy Group" of the parallel E4 Thematic Network project [26].

(iv) The "Criteria for Academic Bachelor´s and Master´s Curricula", proposed by the three Dutch Technical Universities (Delft, Eindhoven, Twente) [27].

It is to be noted that in the Netherlands a binary system of HE exists, reflected in the existence of 'research universities' (including the three TUs) and 'universities of professional education' ("technische hogescholen"), with about 2/3 of the Dutch HE students at universities of professional education. Accordingly, a legal distinction is made between two types of educational profiles (in engineering and other fields): "research oriented" (or "Academic") and "professionally oriented"; the quoted Criteria refer to the first profile only.

(v) The framework for engineering education proposed by the CDIO (Conceive-Design-Implement-Operate Real World) initiative [28]. CDIO is an initiative of three Swedish Technical Universities (Royal Institute of Technology - KTH, Linköping University, Chalmers University of Technology) and the Massachusetts Institute of Technology (MIT): "the Initiative's vision is to provide students with an education stressing engineering fundamentals set in the context of conceiving – designing – implementing – operating (CDIO) real–world systems and products" [29]. The CDIO requirements are summarized in 17 descriptors grouped in 4 "building blocks", that have been compared with the ABET requirements, finding a "strong correlation" in the great majority of cases, and "good correlation" in the others.

(vi) The "Tuning-AHELO Conceptual Framework of Expected/Desired Learning Outcomes in Engineering", the first result of the quoted very ambitious OECD AHELO initiative, published in May 2009 as the result of a comparative review between the EUR-ACE First Cycle outcomes and the ABET criteria, consistent also with a number of other frameworks/sets of Learning Outcomes [14][15]. (a similar framework has been published for Economics). In a sense AHELO (Assessment of Higher Education Learning Outcomes) intends to continue at the global scale the work of the "Tuning" project, with specific reference – at least in the initial phase – to first degrees in the sectors of engineering and economics.

6. Branch Level Descriptors

Depending on the sector of knowledge, sectoral frameworks 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. Engineering is a good example of a sector that requires specific domain descriptors, that can be differentiated according to the different specialties or "branches" (e.g. civil engineering, chemical engineering, etc.). Branch level descriptors characterize outcomes at branch level, including possibly main or core curricula contents and methods, which aim at giving substance to the higher level descriptors.

Significant work is taking place in Europe, at this lower but relevant level, through the activity of "Education Working Parties" of the relevant scientific-technical Associations, or through the initiative of Higher Education Institutions. Generally, these initiatives include the 'translation' of sectoral descriptors into specific branch-level descriptors, the identification of core contents and the identification of scope, depth and breadth of the programmes, a major issue in the engineering area when comparing programmes. Five initiatives may serve as illustration:

(i) EUCEET II (European Civil Engineering Education and Training II), a Thematic Network directly related to the TUNING project and developed under the umbrella of the European Council of Civil Engineers [30], which led to the identification of both generic and specific competences for civil engineering programmes.

(ii) 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" [31]. The core curricula proposed cover about two thirds of the total credits, leaving space for significant modifications and innovations.

(iii) CHEMPASS, an European project involving 13 HEIs, which aims at promoting mobility and attractiveness of European Chemical Engineering Higher Education through a thorough analysis of contents and methods, and through the development of tools for competence evaluation [32].

(iv) The "Recommendation for the development of

consecutive Bachelor's and Master's courses", proposed by the Associations of German Engineers (Verein Deutscher Ingenieure, VDI) and the Society for Chemical and Process Engineering (GVC) both for 'more applications oriented' and for 'more research oriented' profiles [33]. The VDI-GVC recommendation defines: (i) professional profiles and aims for the courses, adopting the EUR-ACE Framework Standards; (ii) qualifications for admissions; (iii) structure of the degree course, including core curricula; (iv) fields of studies; and (v) industrial placements. This proposal is a major recognition of the relevance of the EUR-ACE outcomes and respective descriptors and represents a remarkable example on changes that promote recognition of qualifications.

(v) The initial work at branch level within the Tuning-AHELO Framework [14], for First Cycle outcomes in the branches of electrical, mechanical and civil engineering.

7. Concluding Remarks

The "Bologna Process" aims at creating in Europe "a system of easily readable and comparable degrees" in order to facilitate mobility of students' and graduates' and to promote attractive conditions for third countries to cooperate with European Universities. One of the great assets of Europe is the diversity of its cultures: the "Bologna Process" does not pursue the "uniformity" of the diverse educational systems that derive from such European cultural diversity and can only be harmonized by a gradual spontaneous convergence.

Mutual trust is key for achieving the essential goals of the Bologna Process. To create such trust it is necessary to build transparent and readable academic curricula and professional qualifications. This is achieved through transparent Qualifications Frameworks (QF) and Quality Assurance procedures (QA), recognised and accepted by all partners and stakeholders.

It is clear to the authors of this paper that only "Field-specific" QF and QA approaches can give concrete application and put on solid and practical grounds the "Bologna" objectives.

This paper has tackled these interrelated issues of QF and QA, with particular emphasis on engineering education, and discussed its "accreditation" as entry route for the profession. Several relevant examples of on-going initiatives in designing "Sectoral Frameworks" and "Field-specific" quality assurance methodologies have been critically described: the attention has been focussed on Europe, but global initiatives like the proposed OECD AHELO project and the collaboration between ENAEE and IEA have also been cited.

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