Interdisciplinary projects for Engineering Education: Focusing the Gap Between Teaching Profile and Professional Skills

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The continued globalization of manufacturing and service delivery has led to a concomitant globalization of the engineering profession. Engineers increasingly engage in international projects, including service on multinational teams at different points around the globe, collaborating on a common project through real-time, electronic communication. Effective collaboration requires not only the ability of participants to communicate in a common language, but also the assurance of a common level of technical understanding. Such issues are not trivial, given the global diversity of systems for educating engineers, for different goals in skills, for quality control of their education, and for regulating their professional practice. From the engineering education perspective, the accreditation and assessment of academic programmes is vital in order to maintain the quality and the status of engineering graduates, and hence the technical workforce. Results of a survey of the relevant literature and observations indicate that various accreditation models have been developed regionally, as well as internationally but most of these models seem to be non-uniform, too complex, non-transparent and, moreover, difficult in their application. This leads to confusion and growing concerns about the mutual recognition and global mobility of the engineering profession. As a result, there is an urgent need for a systematic and shared global model of engineering accreditation that can be used to assess global professional skills and attributes of engineering graduates. The aim of the current paper is double. While on the one hand it presents the added value of the EUR-ACE accreditation system as a European best practice example to encourage the mobility of engineering graduates, on the other one it presents a survey on the graduates' opinion on the level of training in the different technical and non-technical areas, comparing the teaching profile with the actual needs of the professional working environments. The survey was carried out in August 2012 by the International Relations Office of the School of Engineering (University of Florence) as preliminary activity to the EUR-ACE accreditation of two curricula.

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1. THE EUR-ACE ACCREDITATION SYSTEM

At the very beginning of the EUR-ACE Accreditation System, a preliminary detailed survey of the standards used by the specialized engineering accreditation agencies throughout Europe revealed striking similarities behind different models. This made the compilation of a set of shared accreditation standards and procedures comparatively easy: the result was the first draft of the "EUR-ACE Framework Standards" [1]. Unlike the old national rules that prescribed inputs in term of subject areas and teaching loads, the EUR-ACE Framework follows the trend of the most recent Standards, and define and require "learning outcomes". This approach has several direct advantages: 1) it respects the many existing traditions and methods of engineering education in Europe; 2) it can accommodate developments and innovation in teaching methods and practices; 3) it encourages the sharing of good practice among the different traditions and methods; 4) it can accommodate the development of new branches of engineering; 5) it assures the quality levels in education of engineering profession.

Today the EUR-ACE is a Europe-based system, run by the European Network for Accreditation of Engineering Education (ENAEE), in which a common quality label (the EUR-ACE® label) is awarded to engineering educational programmes that satisfy a common basic set of standards (the already mentioned "EUR-ACE Framework Standards for the Accreditation of Engineering Programs" that were elaborated within the first EUR-ACE project and are accredited by an Agency fulfilling appropriate Quality Assurance (QA) prescriptions, in particular the "European Standards and Guidelines for Quality Assurance in Higher Education" (ESG) adopted in 2005 within the "Bologna Process" by the Bergen Ministerial Conference. By definition, the EUR-ACE® label ensures the suitability of the accredited programme as entry route to the engineering profession ("pre-professional accreditation"). EUR-ACE has been quoted as an example of good practice of QA in Higher Education in an official report by the European Commission and in an EU publication ("The EU contribution to the European Higher Education Area") issued on the occasion of the March 2010 "Bologna Anniversary Conference" [2].

EUR-ACE system, started in 2007, is a framework and accreditation system that provides a set of standards that identifies high quality engineering degree programmes in Europe and abroad. The EUR-ACE system incorporates the views and perspectives of the main stakeholders (students, higher education institutions, employers, professional organisations and accreditation agencies). Professions such as engineering, medicine, architecture and others carry out work which directly affects the lives of the public. In order to assure the public that these actions and decisions are carried out safely and ethically, graduates must possess specific competences. To ensure that engineering education programmes produce graduates who can demonstrate satisfactory achievement of these competences, they are subject to accreditation by their professional body or another accreditation agency which carries out programme-based accreditation. Engineering programmes that have been accredited by a EUR-ACE authorised agency can be awarded the EUR-ACE label. Among the main characteristics of the EUR-ACE label one can surely recall that it encompasses all engineering disciplines and profiles, is internationally recognised and facilitates both academic and professional mobility. Moreover, it gives international value and recognition to engineering qualifications, and is awarded to programmes which fulfil the programme outcome standards as specified in the EUR-ACE Framework Standards. Finally it respects the great diversity of engineering education within the European Higher Education Area and has created a quality system for accredited engineering degree programmes that share common objectives and outlooks [3].

2. THE EUR-ACE ACCREDITATION MODEL: SELF ASSESSMENT AND EXTERNAL EVALUATION

As above mentioned, the Bologna process has resulted in the EHEA in a common qualifications framework comprising the 1st (bachelor), 2nd (master) and 3rd (PhD) degree cycles. Components of the framework include the EQF (European Qualification Frameworks) qualifications and the ECTS credit system. European standards for internal and external quality assurance are proposed [4].

The EQF relies on stated learning outcomes that are rather general and applicable across all university education sectors. In order to effectively guide education design and accreditation processes for specific fields, more detailed learning outcomes need to be defined. As a result, "sectoral EQFs" emerged with the aim of developing the high-level EQF characteristics into detailed learning outcomes that should characterize specific professional degrees. In the field of engineering, the EUR-ACE framework standards [1] are taking this role. They include three main parts:

- Programme outcomes for accreditation.
- Criteria and requirements for programmes assessment and programme accreditation.
- Procedure for programme assessment and programme accreditation.

2.1. The EUR-ACE Programme Outcomes for Accreditation and Guidelines for Programme Assessment and Accreditation

The EUR-ACE programme outcomes describe the capabilities required of graduates from 1st and 2nd cycle engineering degree programmes. They are structured in six main categories, that is knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice and transferable skills. The 2nd cycle version both adds progression with respect to the 1st cycle outcomes, and adds some additional outcomes, for example "Work and communicate effectively in national and international contexts".

The second part of the EUR-ACE framework standards includes the guidelines for programme assessment and accreditation which are subdivided into five main sections: Needs, objectives and outcomes, Educational process, Resources and partnerships, Assessment of the educational process and Management system. For each of these sections, criteria, requirements and related evidence that should be included in the accreditation documentation are identified.

2.2. EUR-ACE Procedure for Programme Assessment and Accreditation

The EUR-ACE accreditation process can be split in two different, but strictly correlated, phases: a self-assessment phase and, then, an external evaluation.

The self-assessment is implemented by a team according to the request of the accreditation model. The Team is selected inside the school and, often, is constituted by academic, technical and support staff, students. As a result of the self-assessment activity a report - denoted as self-assessment report - is written by the Team with details in accordance with the five main sections mentioned above. A particular attention is voted to the description of the skills regarding the professional figure of engineer. In this case, it is fundamental to distinguish the differences, in terms of skills, among the three different learning levels - bachelor, master and PhD.

The self-assessment report represents the starting point for the second phase of the accreditation process. On the basis of the content of such report and the performance of the learning

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path, an accreditation Team prepares a site visit at the University. This phase is also denoted as peer review. The site visit should include meetings with the university management, academic and support staff members, current and former students, and employers; visits to facilities (libraries, laboratories, etc.); and review of project work, final papers etc. In other words the goal of the site visit is to verify the compliance of the self-assessment activity and the contents of the report with the real situation. For this reason it is fundamental the meetings scheduled with different stakeholders during the site visit.

At the end of the site visit, feedback from the accreditation team is presented during the closing meeting. The accreditation team then writes a report, often denoted as accreditation report. The fulfilment of each individual quality requirement is assessed, using a scale with at least the following three levels: Acceptable; Acceptable with prescriptions; Unacceptable. The overall achievement of the requirements is also evaluated using a scale with at least three levels: Accredited without reservation; Accredited with prescriptions; Not accredited. The university has the opportunity to check the report for factual errors.

The final accreditation decision is taken by an accreditation institution, and may be valid for up to six years with surveillance in the time. After that time, re-accreditation is required.

3. THE EXPERIENCE OF THE SCHOOL OF ENGINEERING IN FIRENZE (ITALY)

In February 2012, the School of Engineering in Firenze has decided to propose two curricula for International Accreditation using the EUR-ACE framework and namely:

- the undergraduate (G) course in Civil, Building/Construction and Env. Eng. (CEA).
- the postgraduate (PG) course in Engineering for preservation of the Env. (ITAT).

The Agency in charge for EUR-ACE in Italy is QUACING (http://www.quacing.it), an agency which has adapted the CRUI (Conference of Rectors of Italian Universities) national model to conformity to EUR-ACE standards. Experimentation on application of the CRUI/EUR-ACE Italian model has started in 2011. The model is highly structured and fulfils the fundamental requirements of most advanced models for quality evaluation and accreditation of university courses in the area of Engineering. The two courses proposed for international certification (CEA and ITAT) have defined the internal working groups and started examining critical issues associated with application of the CRUI/EUR-ACE quality model.

Among the critical issues, it was evident that a detailed decomposition of the learning outcomes/technical skills in the knowledge area of civil engineering was necessary (current models apply Dublin descriptors which are very general). Moreover, it was necessary to implement a survey on the graduates' opinion on the level of training in the different technical and non-technical areas, comparing the teaching profile with the actual needs of the professional working environment. As CEA is a new course, reflecting however a layout generated in 2001 (Bologna agreement- DM509IT) and revised in 2008 (DM270IT), the fundamental skills were inherited by these courses. They were reformulated as EUR-ACE learning objectives, and have been mapped against the Dublin descriptors which have been used up to now). The teaching/learning profile was the same (with different levels in specific areas) for Civil and Environmental engineering (Tab. 1) and a specific set was defined for Building/Construction Engineering (Tab. 2). The survey was run on the graduates from 2008 to 2012, and involved overall 143 students: 75 1st cycle engineering degree, and 68 2nd cycle engineering degree. The survey was designed to avoid overlapping with questions which are already present in the ALMA Laurea questionnaire. The survey was focused on motivation and correspondence between learning profile and required working technical/professional skills.

The main results of the survey for Environmental Engineer (both G and PG) are reported in Fig. 1 and 2. Fig. 1 shows the results of the survey in terms of learning profile, while Fig. 2 shows the difference between the learning profile and the required professional skills (as perceived by the respondents). Similar results are reported in Fig. 3 and Fig. 4 in case of Building/Construction Engineering (again both G and PG). As general comment the learning profile finds a good correspondence with the professional skills, with special reference to the average (G + PG). The fact that some skills have a difference score close to -1 (Capability of running simulations and/or experiments and result assessment; Development of team work attitude; etc.) should be considered a normal outcome, with special reference to the undergraduate learning profile.

Moreover the survey inquired about the reasons for starting the specific university studies (G/PG) and the potential reasons for looking for a different job opportunity. The responses were quite different for the two levels (G/PG); for the two cathegories (Starting University studies/Changing Job); and for the three areas considered (Civ/Edi/Env). The survey also inquired about difficulties encountered in the first impact with the work environment after University studies. Both these surveys are still in progress since data gathering and interpretation is still on the way.

4. CONCLUSION

As our society is facing many grand-challenges and threats, such as the current economic crisis, environ-

Table 1. Learning outcomes: Civil / Environmental Engineering.

1	Scientific fundamentals (Mathematics/Physics/Chemistry)
2	Civil/Structural Engineering (Geotechnics/Structural Mechanics/Theory of structures)
3	Hydraulic Engineering (Fluid Mechanics/Hydrology/Sanitary Engineering)
4	Land Representation Engineering (GIS, Topography)
5	General-purpose SW (Operating systems/spreadsheets/scientific simulation)
6	Specific SW (CAD/specific SW packages such as FE, thermodynamics/heat transfer,...)
7	Materials Engineering
8	Electrical Engineering (plants, electric machines and power electronics)
9	Energy Engineering (Thermodynamics/Heat Transfer)
10	Capability of data gathering (experimental research, field data surveys, including data validation and reduction by statistical methods)
11	Attitude to project work (project organization, civil/environmental engineering)
12	Attitude to group working (teamworking/project study groups)
13	Capability of writing technical reports
14	Fundamentals of economics evaluation and finance tools
15	Professional expertise in quality, safety and environment
16	Interdisciplinary engineering skills (different from Civil/Environmental)
17	Capability of lifelong learning (self-organisation)
18	Principles of Ethics in engineering practice (seminars, part of specific courses)
19	Language skills and capability of working in an international panorama
20	Capability of assessing the environmental performance of a process or of a product (environmental synthesis)
21	Capability of data and information retrieval (from scientific/technical/standards literature;...)
22	Capability of running simulations and/or experiments and result assessment
23	Hydraulic construction works

mental sustainability, climate change and demographic ageing, these are obviously having different impacts on Higher Education. Therefore Higher Education Institutions should, or better have to contribute to identify the ways out. Universities play a key role and should be involved in providing a cutting edge and effective platform for communication and collaboration among all stakeholders in engineering education that share the same interest. Experience has proven the importance of cooperation in the European and trans-European policy context of the Lifelong Learning Programme and TEMPUS and it is precisely this activity that should be promoted in the future. The key theme is now the necessity of collaboration in engineering education in the future and more precisely, how this must contribute to creating and promoting creative and competitive education in the engineering sector and how future engineers should be assured with the necessary skill requirements and subsequently an employment. The methodology to adopt is welcoming contributions and inputs from all actors in engineering education, from students, researchers, teachers, professionals and industry, since the basis of collaboration

Table 2. Learning outcomes: Building/Construction Engineering

1	Scientific fundamentals (Mathematics/Physics/Chemistry)
2	Civil/Structural Engineering (Geotechnics/Structural mechanics/Theory of structures)
3	Building design (Technical architecture and Architectural detailing, Architectural Design and Composition)
4	Construction management, safety and quality assessment
5	General-purpose SW (Operating systems/spreadsheets/scientific simulation tools such as Matlab)
6	Specific SW (CAD/specific SW packages such as FE, thermodynamics/heat transfer,...)
7	Materials engineering
8	Construction control and management
9	Urban analysis and urban planning
10	Capability of gathering data (experimental research, field data surveys including data validation and reduction with statistical methods)
11	Development of project work attitude (project management, civil/environmental engineering)
12	Development of team work attitude
13	Capability of writing technical reports
14	Energy and fluid distribution systems engineering for buildings
15	Professional expertise in quality, safety and environment
16	Interdisciplinary engineering skills (different from Civil/Environmental)
17	Capability of lifelong learning (self-organization)
18	Principles of Ethics in engineering practice (seminars, part of specific courses)
19	Language skills and capability of working in an international panorama
20	Capability to evaluate the performance of the building and its components
21	Capability of data and information retrieval (from scientific/technical/standards literature;...)
22	Capability of running simulations and/or experiments and result assessment
23	Environmental Sanitary Engineering
24	Graphical Information Systems (GIS)
25	Hydraulic engineering (Fluid Mechanics/Hydrology)
26	Land expertise (Topography)
27	Electrical engineering
28	Energy engineering (Thermodynamics/Heat Transfer)

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is to include and not to exclude.

In this context the School of Engineering in Firenze has decided to propose two curricula for International Accreditation using the EUR-ACE framework. As a preliminary step a self-evaluation of the actual curricula was performed, and the paper showed a part of the obtained results. On the one hand it has been shown how it is possible to plan and run a survey investigating correspondence between teaching profile and professional skills. The other hand results of the survey are promising and confirm a satisfactory teaching profile under the several design constraints. They will be used for tuning the teaching profile and adjusting it to the professional skills, moreover it is necessary to present and discuss the outcomes with professional associations, industrial and "political" stakeholders.

Fig. 1. Learning Profile (1 = very bad, 4 = very good).

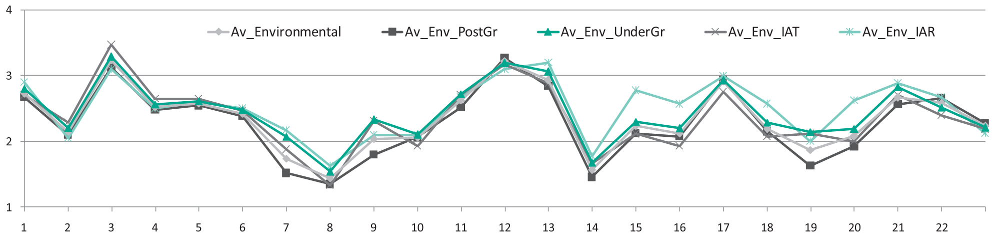


Fig. 2. Difference Learning Profile – Professional skills.

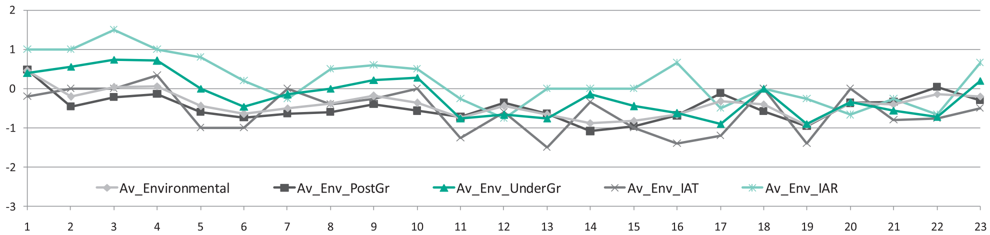


Fig. 3. Learning Profile (1 = very bad, 4 = very good).

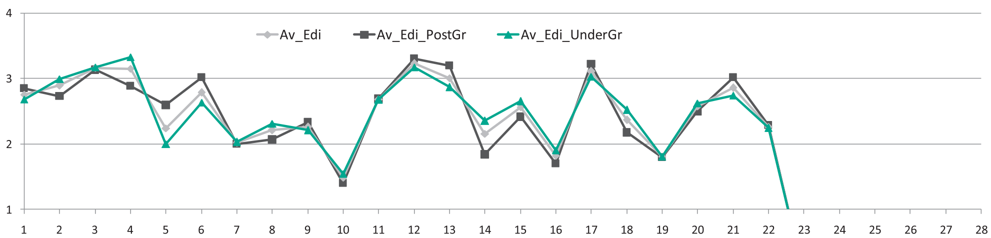
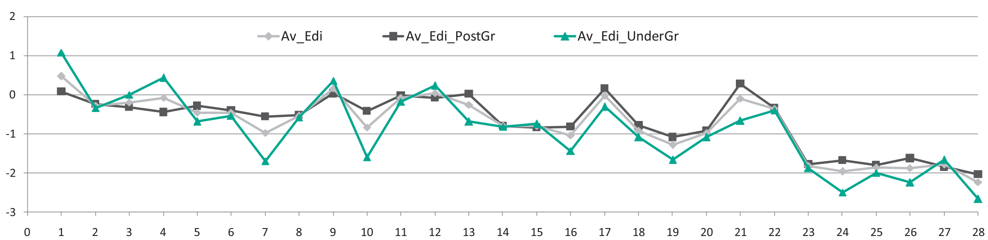


Fig. 4. Difference Learning Profile – Professional skills.



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