Environmental Engineering Education: examples of Accreditation and Quality Assurance

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Conference Topic: Quality Assurance and Accreditation

INTRODUCTION

Environmental engineers respond to the challenges posed by a growing population, intensified land-use, natural resources exploitation as well as rapidly evolving technology. The environmental engineer must develop technically sound solutions with the aims of maintaining or improving environmental quality, complying with public policy, and optimizing the utilization of resources. The globalization of challenges and problems to be faced leads to the globalization of the engineering profession which requires not only the capacity to communicate in a common technical language, but also the assurance of an adequate and common level of technical competences, knowledge and understanding.

The application of the accreditation model EURACE®, and of the National Italian Degree Courses Accreditation System (ANVUR-AVA) to the multidisciplinary first cycle degree in Civil, Building and Environmental Engineering and the more specific second cycle degree in Environmental Engineering carried out at the University of Firenze is presented.

Particularly, the critical issues to assure the quality and the status of environmental engineering graduates, in terms of applying knowledge capacities and technical innovative competences, according to the more engineering focused EURACE® skill descriptors, if compared with the Dublin descriptors, are emphasised.

In addition, the involvement of the students and the professional working world, graduates included, in the definition of learning outcomes and expected skills, the assessment of the system for educating engineers in communicating knowledge and understanding, making informed judgments and choices, capacities to lifelong learning and the promotion of innovative aspects related to the environmental engineering education are further investigated.

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1 ENVIRONMENTAL ISSUES AND HIGHER EDUCATION

In the framework of EHEA the technical and methodological aspects related to protect the environment and to enhance the natural resources are of paramount importance. The environmental engineer is a technician devoted to this, i.e. with specific expertise on the sustainability of human presence in the environment.

The general objectives of the environmental engineer are to establish actions of environmental sustainability as well as to verify progress toward global goals or international commitments. In particular, since the environmental issues are without boundaries, and they involve many different professions and competences, the environmental engineer must have a multidisciplinary and interdisciplinary approach to adequately answer to the demand of technical innovative knowledge at global scale.

Since the United Nations Conference on the Human Environment [1] international environmental treaties have been created at an unprecedented rate. Already in 1992 at the United Nations Conference on Environment and Development, informally known as the “Earth Summit”, held in Rio de Janeiro, Brazil, three new global environmental agreements were signed” [2].

The UN sought to help Governments rethinking economic development and finding ways to halt the destruction of irreplaceable natural resources and pollution of the planet. Governments recognized the need to redirect international and national plans and policies to ensure that all economic decisions fully took into account any environmental impact.

All the concepts above have been confirmed and updated at the United Nations Conference on Sustainable Development “Rio+20” [3][4], i.e. an unprecedented opportunity to build “The Future We Want”, as it is aiming for political consensus on a global plan which balances and integrates economic and social development and environmental protection. Rio+20 in its final results, includes, in fact, recommendations to “*improve the capacity of education systems for sustainable development, including the development of curricula around sustainability and the teaching of sustainable development as an integrated component across disciplines*”.

In this context, the crucial role of education of “environmental players” (technicians, researchers, engineers….) is highlighted starting from the assurance of an adequate and common level of competencies, knowledge and understanding, to tackle with present and future global environmental challenges.

Furthermore, considering the most recent documents on climate [5], several professional skills can be traced to the Environmental Engineer – probably the professional figure in the engineering field with the most developed interdisciplinary education. A non-exhaustive list of characterized professional skills is the following: management of water cycle (including drinking water and sanitation), air quality, CO2 emissions, renewable energies and transition to green economy, chemicals and waste, disaster risk reduction.

As a consequence, Higher Education plays a very important role in the implementation of Engineering Curricula, also foreseeing consultation with different stakeholders and interested parties, such as students and the professional working world for the definition of learning results and expected abilities. Particularly, the learning needs of the interested parties are analysed with reference to the professional working world, graduates included, as well as the career opportunities. Within the consultations, the career opportunities are evaluated also together with the needed professional skills.

The career opportunities are differentiated for the first and second cycle graduates. For both types of graduate, the consultations can involve the main subjects representative of the world of production, industrial and handcraft associations, associations of professionals as well as services providers and territorial government subjects.

2 ENGINEERING EDUCATION ACCREDITATION MODELS

The need to tackle new global as well as local environmental challenges, demands for technicians with an adequate and common level of technical competences, knowledge and understanding. The higher education system worldwide needs to adopt an accreditation system in order to provide a set of measures to assess the quality of degree programmes. The Europe-based EURACE® system, currently operated by ENAEE- European Network for Accreditation of Engineering Education, can represent the proper framework and accreditation system in order to provide an effective tool to assess the quality of engineering degree programmes in Europe and abroad.

In addition, many, not always according to common standards, are the evaluation measures and procedures taken by European governments, agencies and authorities at national level.
The Environmental Engineering Education at University of Firenze is described with reference to the application of the EURACE® model [6] as well as the Italian ANVUR-AVA system [7]. The quality and the status of environmental engineering graduates, and particularly the expected learning outcomes are assessed according the Dublin Descriptors as well as the more engineering focused EURACE® skill descriptors.
The two different accreditation systems and procedures, both still in progress, are briefly described and discussed, considering accreditation a strong means towards the education of competitive highly-qualified global environmental engineers. The importance of the accreditation to guarantee the quality and the status of environmental engineering graduates, particularly in terms of applying knowledge capacities and innovative interdisciplinary competences is also underlined.

2.1 The EURACE® model

In the field of Engineering Education, a good example of instrument for international recognition of qualifications is the decentralized Europe-based accreditation system EURACE® [6], which delineates the shared framework for outcome-based accreditation of engineering programmes.
The system is run by the European Network for Accreditation of Engineering Education (ENAEE) within the "EURACE Framework Standards for the Accreditation of Engineering Programs" [6].
With reference to the "ESG - European Standards and Guidelines for Quality Assurance in Higher Education" (ENQA, 2009) adopted in 2005 within the "Bologna Process" by the Bergen Conference (2005), EURACE® authorised agencies, fulfilling appropriate Quality Assurance prescriptions, can award the EURACE® label.
Particularly, the EURACE® system, started in 2007, provides a set of standards that identifies high quality engineering degree programmes in Europe and abroad. Within EURACE®, the common quality EURACE® label, is awarded to engineering educational programmes that satisfy the common set of standards. By definition, the EURACE® label ensures the suitability of the accredited programme as entry route to the engineering profession, a sort of "pre-professional accreditation" [8].
Among the main characteristics of the EURACE® label one can surely recall that it encompasses all engineering disciplines and profiles, it is internationally recognised and facilitates both academic and professional mobility. Moreover, it gives international value and recognition to engineering qualifications, since it is awarded to programmes which fulfil the programme outcome standards as specified in the EURACE® Framework Standards. The EURACE® Framework Standards are valid for all branches of engineering and all profiles of study, and distinguish only between First and Second Cycle programmes, as defined in the European Qualification Frameworks [9].
The EURACE accreditation process can be split in two different, but strictly correlated, phases: a self-assessment phase and an external evaluation phase [6].
According to the accreditation model the self-assessment is implemented by an Internal Quality Working Group, a group composed by academic, technical and support staff, students, the interested parties, in general, participating to the learning system of the degree course.
The product of the self-assessment activity is the self-assessment report. On the basis of the content of the self-assessment report and the performance of the learning path, the second phase of external evaluation or peer review phase is organized through a site visit of an Accreditation Team.
The objective of the site visit is to verify the compliance of the self-assessment activity and the contents of the report with the actual situation. The site visit includes meetings with the university management, academic and support staff members, current and former students, employers and with all the different stakeholders and interested parties; visits to facilities (libraries, laboratories, etc.); review of project works, final documents etc. At the end of the site visit, during the closing meeting, feedback from the accreditation team is presented. 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: 1) Acceptable; 2) Acceptable with prescriptions; 3) Unacceptable. The overall achievement of the requirements is also evaluated using a scale with at least three levels: 1) accredited without reservation; 2) accredited with prescriptions; 3) not accredited. The university has the opportunity to check the report for factual errors [6].
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, reaccreditation is required.

In Italy, the accreditation body for Italian Engineering Programmes based on the EURACE® model, that is authorized to award the EURACE® label is QUACING-Agenzia per la Certificazione della Qualità e l'Accreditamento EURACE® dei Corsi di Studio in Ingegneria, the Agency for Quality Assurance & Accreditation of Engineering Programmes (www.quacing.it).

2.2 The Italian ANVUR-AVA system

In Italy, the university and research assessment, nowadays, is regulated by ANVUR - Agenzia Nazionale per la Valutazione dell'Università e della Ricerca (National Agency for University and Research Assessment, www.anvur.org) through AVA-Autovalutazione, Valutazione periodica, Accreditamento (Self-assessment, Periodic Assessment and Accreditation) [7].
The AVA system defines the set of ANVUR activities based on the national regulations, which provide the introduction of an initial and periodic accreditation system of degree courses and of higher education institutions, a periodic assessment of the quality, efficiency and results achieved by the universities and the strengthening of the system of self-assessment of the quality and effectiveness of teaching and research activities of universities. ANVUR has the duty of setting methodologies, criteria, parameters and indicators for the accreditation and periodic assessment. ANVUR is also concerned with the verification and monitoring of parameters and indicators for accreditation and periodic assessment for the annual resources allocation to universities. The fundamental elements of the AVA integrated system derived in large measure by the national legislation as well as the Standards and Guidelines for Quality Assurance in the European Higher Education Area [10] approved by the European Ministers Conference in Bergen [11], within the "Bologna Process".
The Italian Higher Education Institutions started to apply the AVA system in February 2013 with the initial accreditation process and continued in 2014 with the annual accreditation process. In AVA system the expected learning outcomes for degree courses are described as general descriptors, i.e. their characteristics make them applicable to a large range of disciplines and profiles and they have to take into account the peculiarities of the national higher education system. A Fundamental tool of AVA system is SUA - Scheda Unica Annuale del Corso di Studio (Annual Single Form of Degree Course) that contains the description of degree course in terms of objectives, learning outcomes, based on the Dublin Descriptors [13], professional skills, courses offered, involved professors, organisations, structures, facilities, statistics on enrolled students, opinions of students and graduates as well as connection with the labour market creating an important means to present University Degree Courses and an effective mean for the accreditation and quality assurance of Universities degree Courses.

3. ENVIRONMENTAL ENGINEERING EDUCATION AT THE UNIVERSITY OF FIRENZE (ITALY)

The School of Engineering of the University of Firenze offers two degree courses in Environmental Engineering: the multidisciplinary First Cycle Degree – FCD in Civil, Building and Environmental Engineering and the more specific Second Cycle Degree – SCD in Environmental Engineering.
The FCD has as main aim the education of technicians with a suitable basic scientific competences and understandings of methodologies and technical-specific skills of Civil, Building and Environmental Engineering. The degree course refers to four types of branches: Structures, Infrastructures, Building and Environment. Every branch corresponds to a specific educational path in which professional competences are developed starting and continuing a common core basis.
The SCD course in Environmental Engineering aims at educating high-level professionals that have not only an advanced knowledge of general environmental and territory engineering methods and contents applied to environmental protection and control but also scientific skills on analytic and numerical modelling. In addition also economical and regulatory aspects are present allowing a cultural/technical growth and capabilities for responsibility assumption.
In February 2012, the School of Engineering of the University of Firenze has decided to propose the two degree courses for the International Accreditation using the EURACE® Framework Standards [6]. As required, the two courses identified the Internal Quality Working Group, named GAV - Gruppo di Autovalutazione (Self-Assessment Group). As a result of the self-assessment activity, a self-assessment report has been written by the Internal Quality Working Group in accordance with the guidelines for assessment and accreditation. In the implementation of the accreditation model a particular attention has been 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 of the "Bologna process", i.e. bachelor, master and PhD. The self-assessment report represents the starting point for the second phase of the accreditation process. The Internal Quality Working Group has completed the two self-assessment reports in February 2013 [12]. The self-assessments report includes data on the degree courses, graduated students, the efficiency of their learning processes and the description of all course activities. In order to identify the EURACE® required learning outcomes and the degree courses expected learning results, an evaluation of the Dublin Descriptors [13] based on the EURACE® Learning Outcomes, that directly underline the aspects related with the engineering analysis, design and practice, has also been carried out. Particularly for each of the six learning outcomes of EURACE® model, relevant expected learning criteria for FCD and SCD programmes' graduates have been recognized (*Table 1*).

Table 1. EURACE® Learning Outcomes and Dublin Descriptors Learning Outcomes for the First Cycle Degree Course.

EURACE® Learning Outcomes	DUBLIN DESCRIPTORS Learning Outcomes
1. Knowledge and Understanding	
Knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering.	Knowledge and understanding
A systematic understanding of the key aspects and concepts of their branch of engineering.	
Coherent knowledge of their branch of engineering including some at the forefront of the branch	
Awareness of the wider multidisciplinary context of engineering.	
2. Engineering Analysis	
The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods.	Applying knowledge and understanding
The ability to apply their knowledge and understanding to analyse engineering products, processes and methods.	
The ability to select and apply relevant analytic and modelling methods.	Making informed judgements and choices
3. Engineering Design	
The ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements.	Making informed judgements and choices
An understanding of design methodologies, and an ability to use them.	Applying knowledge and understanding
4. Investigations	
The ability to conduct searches of literature, and to use data bases and other sources of information.	Knowledge and understanding
The ability to design and conduct appropriate experiments, interpret the data and draw	
Workshop and laboratory skills.	
5. Engineering Practice	
The ability to select and use appropriate equipment, tools and methods.	Applying knowledge and understanding
The ability to combine theory and practice to solve engineering problems.	Knowledge and understanding
An understanding of applicable techniques and methods, and of their limitations.	Applying knowledge and understanding
An awareness of the non-technical implications of engineering practice.	Making informed judgements and choices
6. Transferable skills	
Function effectively as an individual and as a member of a team.	Communicating knowledge and understanding
Use diverse methods to communicate effectively with the engineering community and with society at large.	
Demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice.	
Demonstrate an awareness of project management and business practices, such as risk and change management, and understand their limitations.	
Recognise the need for, and have the ability to engage in independent, long-life learning.	Knowledge and understanding

In addition, the two Degree Courses had to apply for the Italian national Accreditation through the AVA System and SUA [13].
As already mentioned, within SUA, the expected learning outcomes of the quality assessment are based on Dublin Descriptors. Particularly, at the simultaneous phase of AVA System (and EURACE® system) implementation, the expected learning outcomes were based on the first two Dublin Descriptors, “knowledge and understanding” and “applying knowledge and understanding”.
As far as the FCD is concerned, while the basic knowledge is developed in common in the three different curricula, i.e. civil, building and environmental engineering, the differences between them are within the characteristic skills and integrative knowledge *(Table 2).* Particularly, the Environmental curriculum is focused on the aspects related to geology and geomorphology; expertise in environmental and territory engineering (i.e. issues and techniques related to pollution, waste treatment, water protection); subjects related to hydrology and hydraulic engineering; criteria for energy and environmental evaluation of buildings and electrical systems for the environment.

Table 2. Learning outcomes of the First Cycle Degree programme in Civil, Building and Environment Engineering with reference to the Environmental Curriculum.

DISCIPLINES & ACTIVITIES		Knowledge and understanding	Applying knowledge and understanding
Basic Knowledge		Sharing a reference language	To interpret and to solve typical issues of environmental engineering.
	Mathematics, Informatics and Statistics		
	Chemistry & Physics		
Characteristic Skills		Representation tools; principles of fluids, solids, soil, and structural mechanics	To represent, to analyse and to solve typical issues of environmental engineering; to collaborate and coordinate the activities with industry experts; to organize and to manage production activities; lifelong learning development particularly related to technology innovation.
	Civil Engineering		
	Environment and Territory Engineering		
	Security, Civil, Environmental and Territory Protection		
Integrative Knowledge		Main technological aspects of the use of materials; main elements of the representation of computational graphic; safety and quality management in industry	Monitoring and control of: quality management systems; the various aspects of the industrial risk.

The characteristic skills and integrative knowledge of the SCD in Environmental Engineering are developed within the first year of the learning programme as completion of the FCD programme as well as with the activation of specific programmes. Further characterizations and specific knowledge of the individual study programme concern with elective courses and project works of the student *(Table 3).* In both the cycles, knowledge and understanding are developed through the use of traditional forms of teaching (lectures, practice exercises, etc.). Applying knowledge and understanding concern with practice exercises in classroom or laboratory, both individual and in groups. The procedures to assess the actual achievement of educational objectives are done through exams that can be written, oral or the mix of the two, at the end or during the lectures period (i.e. intermediate tests). Where provided, the assessment can include the evaluation of project works and specific laboratory reports, particularly related with “applying knowledge and understanding” of the integrative disciplines.
The work for learning outcomes definition of the involved degree programmes, includes also a definition of graduates career opportunities, differentiated for first and second cycle graduates.
The First Cycle Degree graduate can develop careers mainly as professionals or in enterprises, public and private companies in the field of planning, design, implementation and management of structures, monitoring systems for environment and territory control, for soil protection, for waste, raw materials

and environmental resources management, for environmental reclamation, for environmental impact assessment of plans and structures and in production processes.
On the other hand, the typical professional areas of the Second Cycle Degree graduate are the innovation as well as the development of advanced design, planning, and complex systems management; as professionals, as well as in manufacturing or services enterprises, or in the public administration. The graduates can be employed in enterprises, public or private agencies, professional consulting companies providing design, planning, realization and management of structures and monitoring systems for environment and territory, soil protection, waste, raw material and environmental, management of geological and energy resources; for environmental impact assessment of plans and structures.
The validation of results can be carried out on the basis of a suitable survey addressed to the professional working word and in particular to the employed environmental engineers (3 – 5 years after graduation). The main aim of the survey is to evaluate the effective application of acquired engineering professionals skills.

Table 3. Learning outcomes of the Second Cycle Degree programme in Environmental Engineering.

DISCIPLINES & ACTIVITIES	**Knowledge and understanding**	**Applying knowledge and understanding**
Characteristic Skills for Environmental Engineering	Territory and environment protection. Plants and systems of environmental quality and energy production. Environmental risk management	To identify, to formulate and to solve complex problems in innovative ways that may require an interdisciplinary approach; to design and to manage complex environmental systems and processes.
Integrative Knowledge	Specific and transversal knowledge also from the scientific and theoretical point of view	Enhancement of the capacity to interpret, to characterize and to solve complex engineering problems that require a typical interdisciplinary approach.

4. CONCLUSIVE REMARKS

The Environmental Engineering Education at University of Firenze is described with reference to the application of accreditation and quality assurance systems such as the European EURACE® model and the Italian ANVUR-AVA system.
The importance of the accreditation to guarantee the quality and the status of environmental engineering graduates is highlighted through the definition of the learning outcomes. Particularly, on the basis of learning outcomes related to “knowledge and understanding” and “applying knowledge and understanding”, two environmental engineering programmes, the First Cycle Degree and Second Cycle Degree running at the School of Engineering, within the accreditation system, are discussed.
The self-assessment reports, in the frame of the EURACE® model, have been submitted. To complete the accreditation procedure for the two involved degree courses, the accreditation site visit, from QUACING-Agenzia evaluators, has been programmed to take place by the end of 2014.
As far as the ANVUR-AVA System is concerned, the two degree courses have been awarded with the initial and annual accreditation of the Italian Ministry of Education, University and Research. The accreditation process has to be periodically implemented.
As far as future developments are concerned, since the learning outcomes of the two environmental engineering programmes, have been defined also on the basis of the needs of interested parties and career opportunities resulting by the consultation with the interested parties, their reliability can be validated on the basis of a dedicated survey addressed to the working world and the graduates.

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