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DESIGNING OF CURRICULA OF ENVIRONMENTAL ENGINEERING AND CONSTRUCTIONS ENGINEERING FOR SUSTAINABILITY

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ABSTRACT

The experience carried out at the University of Florence, Department of Civil and Environmental Engineering, in designing two new undergraduate curricula in “Environmental Engineering” and “Civil and Building Engineering for sustainability”, is reported. The bachelor in Environmental Engineering aims to train engineers capable of working in the field of protection of environment, territory and natural resources. The bachelor in Civil and Building Engineering for sustainability aims to train engineers capable of working in the field of structures, infrastructures, and constructions in general, as well as management and safety of construction processes. The development of the two curricula was based preliminarily on a national and international survey of degree programs of the same type and with shared learning outcomes. Subsequently, labour market needs were identified starting from discussions with all stakeholders, students and professors included. Teaching methods and methods for assessing students' preparation have also been revised and the teaching plan of both curricula is characterized in the third year by the presence of multidisciplinary laboratories, focused on the most characterizing themes of each

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programme and the different disciplines with integrative and specific in-depth characteristics. Finally, a thorough design of the two courses contents has been initiated, based on the definition of the general educational objectives and the specific disciplines.

1 INTRODUCTION

Climate change and environmental degradation are now globally perceived as the greatest threat to Europe and the world: national and supranational institutions are pursuing strategies for a resource-efficient economy to face the challenge of sustainability. In particular, the European Commission through the "European Green Deal" (Fetting 2020) marks the roadmap to make the EU economy sustainable and aims to achieve this goal by transforming climate related problems and environmental challenges (environmental sustainability, resilience, decarbonisation, etc.) into opportunities with economic growth that is decoupled from the use of resources, with no person and no place being neglected.

The strategic objective is to transform Europe into the first block of countries with zero climate impact by 2050 (IPCC 2022). In this context, it is therefore necessary to strengthen and expand professional skills in numerous areas typical of civil, building and environmental engineering. The policies for the so-called "ecological transition" and the European directives on the circular economy, which have a prevalent part in the Recovery Fund, in order to be implemented need adequate financial instruments, and, above all, qualified and trained personnel to address these challenges.

The establishment of new degree courses is therefore perfectly in line with the strategic development guidelines of the European Commission envisaged in the Next Generation EU Plan and with the Italian National Recovery and Resilience Plan, which identifies the "Green revolution and ecological transition" and the "Infrastructures for sustainable mobility" among the six structural thematic areas of intervention.

In this context, the Department of Civil and Environmental Engineering (DICEA - *Dipartimento di Ingegneria Civile e Ambientale*) of the University of Florence has found the reasons to propose, starting from the A.Y. 2023-2024, the activation of a new Degree Course in Environmental Engineering (*Ingegneria Ambientale* - IAL), in the degree class L-7 Civil and Environmental Engineering, focusing more on the specific contents of Environmental Engineering and a strong revision of the current three-year degree in Civil, Building and Environmental Engineering, developed on three curricula: civil, building and environment. This existing course was deeply modified, starting from the name, which from 2023/2024 will be changed into Civil and Building Engineering for Sustainability (*Ingegneria Civile e Edile per la sostenibil*ità - ICE), and including all its most fundamental aspects (e.g. learning outcomes, career opportunities, study programs, etc.) with the aim of effectively defining a brand new course of study.

In designing the newly established IAL study program and revising the existing one, reference was made to the needs for innovation and sustainability coming from the labour market and, at the same time, to the priorities and objectives to which the University of Florence inspires its strategy of qualification and sustainability of the educational offer.

The review of the educational offer as a whole also stems from the results of a survey carried out to analyse the placement of graduates in civil engineering, building engineering and environmental engineering in the labour market (AlmaLaurea 2023), as well as it emerges from the investigation preliminarily carried out at national level on the three-year degree courses in the degree class L-7 Civil and Environmental Engineering.

The new study program and the revision of the current one are consistent with what observed in the largest Italian universities as well as in prestigious foreign universities, such as Harvard University, Stanford University, University of Cambridge and ETH Zurich.
From a methodological point of view, the definition of the two programs is in line with the solicitations coming from the world of industry and professions (Duderstadt 2010; Eckert et al. 2019; Van der Vleuten et al. 2017), and with the results of the surveys conducted by prestigious engineering training schools which have begun to question on the challenges that fast societal change poses to engineering education (Graham 2018).
In particular, attention was paid to the period of great change in the training of engineers in order to respond adequately to the demands of society. The change includes engineering study programs with a more relevant social-education component and with a greater focus on skills. Greater flexibility for students in the composition of their curricula, greater attention to multidisciplinary learning, increased students' awareness of the impact of technologies on the socio-economic context, and greater attention to the acquisition of soft-skills, are also fostered.
A study by UCL (2018), in this regard, reveals the importance of associating "soft-skills" with the "hard-skills" typical of engineering education, to focus on "inclusion and diversity" through more inter and multi-disciplinary curricula, focusing on disciplines that concern the development of an engineering career, the acquisition of know-how skills through the development of real projects and the growth of the international dimension through experiences abroad.
Formally, whether it is a newly established program or the revision of an existing program, the first phase of planning concerns the definition of learning outcomes, i.e. the set of knowledge and skills that characterise the cultural and professional profile, to which the curriculum is aimed at. This is followed by the definition of the specific Didactic Regulation for the Degree Course, i.e. the set of rules that regulate the specializations or curricula of the study programme, according to the University teaching regulations, drawn up in compliance with the reference legislation.
The final phase concerns the definition of the specialisations or curricula in which the degree course is organized and the set of university and extra-university training activities specified in the teaching regulations of the degree course for the purpose of obtaining the relevant qualification.
In the following, the methods on which the design of the new degree course as well as the revision of the existing one are based, are briefly described. The description concerns the national and international point of view on the central role of engineering degree courses and of engineers in framing the society of knowledge. The engineering education able to support and promote the changing is also discussed. The results achieved are finally described.

2 METHODOLOGY

The labour market becomes the privileged reference in the definition of training courses. In fact, there are numerous studies that have as a final result the definition of the professions that society will need in the future (WEF 2020).
Among the professions identified as strategic for the future, some are certainly attributable to the field of engineering (NAE 2017).
Nevertheless, some difficulties for engineering training schools in meeting the needs of a rapidly evolving society that poses global challenges, such as environmental and economic sustainability, protection and safeguarding of health and the environment are recognized. In the context of such challenges, the role of the Engineer is to imagine, implement and manage the technical infrastructure for sustainable change

and therefore the training and qualification of the engineers of the future plays a central role for the construction of the knowledge society (Morell 2010; Apelian 2007).
Specifically, among the challenges, the following can be traced back to ICE and IAL degree courses: i) provide access to clean water; ii) restore and improve urban infrastructures; iii) assess life-cycle of materials and structures; iv) use innovative and recyclable materials; v) design Nearly Zero-Emission Building (NZEB); etc.
Thus arose the need to respond to the necessities expressed by society with knowledge, skills and attitudes developed by students during their training in engineering schools for modern professional figures of engineers who know how to support and promote sustainable change. In this context, the learning outcomes of the two degree courses have been defined with reference also to the recommendations reported by ASME (2023) on: a) development of higher standards of professional and communication skills; b) increased flexibility in the study programmes. The definition of the learning outcomes, however, concerns the characterization of the cultural and professional profile, i.e. the set of knowledge and skills each curriculum aims to provide. Once the professional profiles and learning outcomes have been defined, the construction of the didactic regulation of the degree course is required. Each teaching regulation determines: a) the denominations and educational objectives of the study courses, indicating the relative classes to which they belong; b) the general framework of the training activities to be included in the curricula; c) the credits assigned to each training activity and to each area, referring them to one or more scientific-disciplinary sectors as a whole; d) the characteristics of the final exam for obtaining the degree.
Every year the Italian *National University Council* (CUN 2022), with reference to the regulatory context and the ministerial indications for the quality assurance of the Degree Programmes, provides indications for an effective drafting of regulations and the elaboration of a valid and well-structured teaching offer. On the basis of the regulation that constitutes the general framework of the Degree Course, different curricula may be developed within the same Course.
Both degree courses have been divided into three curricula that represent different education paths, but are aimed at achieving the same training objectives. Each curriculum is aimed at directing the training of students towards one of the professional profiles identified and to acquire skills directly usable in the world of work.
Also, as required by Italian Ministerial Decree No. 133/2021, the teaching plan is characterised by high flexibility.
Besides all the aspects described above and the specific disciplines of engineering, the contents of the two degree course are defined to adequately respond to some of the Sustainable Development Goals defined by the United Nations in the 2030 Agenda, namely: SDG 9-Industry innovation and infrastructure; SDG 11-Sustainable cities and communities; SDG 13-Climate action. The SDGs in IAL are integrated with: SDG 6-Clean water and sanitation; SDG 14-Life below water; SDG 15-Life on land.

3 RESULTS

The Degree Course in *Civil and Building Engineering for sustainability* aims to train first-level engineers of the degree class L-7 Civil and Environmental Engineering that add to the solid traditional technical training, also the ability to contribute to the sustainable development of the territories and the communities within which engineering works fit, ensuring that technological applications are consistent with the needs of future generations.
Classes which refer to the contents of the most characterising disciplines of civil and building engineering, suitably organised, so as to train technicians with a highly multidisciplinary preparation, essential for responding to the needs expressed by the

labour market and by a multiplicity of stakeholders and higher academic education, with particular reference to the following areas:

a) design, construction and operation of buildings and structures taking into account the sustainability of exploitation of natural resources and the possibility of recycling or reusing materials and waste;
b) design of hydraulic and geotechnical civil works;
c) planning, management and maintenance of works, plants, infrastructures and urban and territorial systems, and of civil systems and installations for the environment and the territory, also for the purpose of prolonging the life cycle and sustainability of the impacts generated;
d) acquisition and management of geospatial data;
e) management and safety of construction processes.

Three professional profiles with multiple professional outlets have been identified:

- Technician of structures, infrastructures and civil works;
- Technician for buildings and building systems;
- Technician for the management and safety of construction processes.

The course is then structured in three curricula (Table 1.1, 1.2 and 1.3), aimed at covering the main application areas of civil and building engineering and at training students towards one of the professional profiles identified:

1. *Structures and Infrastructures*: aimed at training technicians capable of operating in the field of structures, infrastructures and civil structures, through the use of both traditional and innovative, eco-compatible, recycled systems and materials and the integration of technologies based on renewable energy and water reuse;
2. *Building systems*: aimed at training technicians capable of operating in the field of building systems, using traditional and innovative techniques and materials, in the context of sustainability, from both an energy and environmental point of view;
3. *Construction safety management:* aimed at training technicians who have knowledge and skills in the management and safety of construction processes, also with attention to the concept of social sustainability.

Table 1.1 First year Study Plan of Degree Course in Civil and Building Engineering for sustainability.

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
I	Mathematical Analysis I	9	Physics	9
	Geometry	6	Statistics	6
	Computer Science Laboratory	6		
	Chemistry/Materials Technology*			12
Structures and Infrastructures				
I	Design/Geomatics*			12
Building Systems/Construction Safety Management				
I	Design/Fundamentals of Building Design*			12

**The course is a joint course composed of two different integrated sectors.*

Table 1.2 Second year Study Plan of Degree Course in Civil and Building Engineering for sustainability.

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
II	Continuum Mechanics	6	Structural Mechanics	6
	Thermodynamics and Heat and Mass Transfer	9	Geotechnics	9
	Foreign language (English)			3
Structures and Infrastructures				
II	Mathematical Analysis II	9	Fluid Mechanics	9
	Applied Geology	6	Fundamentals of Building Design or** Hydraulic Infrastructures	6
Building Systems				
II	Mathematical Analysis II	6		
	Building Technology and Sustainability*			12
	Building Process Digitization Laboratory*			12
Construction Safety Management				
II	Mathematical Analysis II	6	Sustainable Water Resources and Waste Management*	9
	Building Process Digitization Laboratory*			12

**The course is a joint course composed of two different integrated sectors.*
***Mandatory elective course: students are requested to select only one between the two courses proposed.*

Table 1.3 Third year Study Plan of Degree Course in Civil and Building Engineering for sustainability.

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
III	Structural Design	9	Traineeship	3
	Structural Analysis	6	Final Exam	3
	Elective Courses			12
Structures and Infrastructures				
III			Transportation	9
	Sustainable Structures Design Laboratory or** Sustainable Infrastructures Design Laboratory			15
Building Systems				
III			Energy and Environmental Building Assessment	6
			Sustainable Water Resources Management*	6
	Sustainable Buildings Design Laboratory			12
Construction Safety Management				
III			Transportation	9
			Building Production and Safety	6
	Sustainable Construction Management Lab			12

**The course is a joint course composed of two different integrated sectors.*
***Mandatory elective course: students are requested to select only one between the two courses proposed.*

The Degree Course in *Environmental Engineering* aims to train first-level engineers capable of operating in the field of environment, territory and natural resource protection.
Classes referring to the contents of the most characteristic disciplines of environment and territory engineering are provided, suitably organised, so as to train technicians with a highly multidisciplinary preparation, indispensable for responding both to the needs expressed by the labour market and by a multiplicity of stakeholders, and to higher-level academic training, particularly in the following areas:

a) prevention, control and remediation of the negative impacts on the environment of the various human activities,
b) environmental impact assessment of structures, infrastructures, urban areas, production activities and services,
c) prevention, monitoring and rehabilitation of hydrogeological instability phenomena and slope instability, management of river basins and the coastal environment,
d) management of natural resources with a view to sustainable development,
e) technical-managerial coordination in the context of optimal integration of processes related to Health, Safety and the Environment.

Three professional profiles with multiple professional outlets have been identified:

- Technician of Health, Safety and Environment (HSE);
- Technician for the protection of natural resources and sustainable development;
- Technician for the assessment and mitigation of natural and anthropic risks.

The Course is structured in three curricula (Tables 2.1, 2.2 and 2.3), aimed at covering the main application areas of environmental engineering and at training students towards one of the professional profiles identified:

1) *Safety, health and environmental quality*: aimed at training technicians who have knowledge and skills to support and verifying the full and integrated implementation of processes related to health, safety and the environment with the aim of contributing to the overall efficiency of companies/organisations;
2) P*rocesses and technologies for sustainable development*: aimed at training technicians capable of technical support during the construction and operation of technological plants, whether private or public utility, for the supply of drinking water and the treatment of wastewater, solid and liquid waste and gaseous emissions;
3) *Monitoring of the territory and mitigation of natural and anthropic risks*: aimed at training technicians capable to collaborate in all activities related to the surveying, management and protection of territory and urban areas also in the context of climate change.

According to the provisions of the D.M. 270/2004, the two Courses are structured in 3 years during which students must acquire 180 credits.
The teachings of the first year are almost entirely in common among all curricula and between the two Degree Courses. The second and third year, on the other hand, provide for each Degree Course teachings in common and others specific for each curriculum. Both courses and curricula require the presence of at least 12 ECTS freely chosen by the student, the assessment of the knowledge of English language (level B2), an internship in the third year and a final exam of 3 credits. The internship is 3 ECTS with the exception of IAL-HSE which has an internship of 6 ECTS.
The study plan also includes the presence of multidisciplinary laboratories, all located in the third year, focused on the most characterizing topics of the Degree Course and teachings with a supplementary and specific in-depth nature.

Table 2.1 First year Study Plan of Degree Course in Environmental Engineering

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
I	Mathematical Analysis I	9	Physics	9
	Geometry	6	Statistics	6
	Computer Science Laboratory	6	Geomatics and GIS	9
	Chemistry/Environmental Chemistry*			12
	Foreign language (English)			3

**The course is a joint course composed of two different integrated sectors.*

Table 2.2 Second year Study Plan of Degree Course in Environmental Engineering

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
II	Mathematical Analysis II	6	Structures	9
	Continuum Mechanics	6	Fluid Mechanics	9
	Thermodynamics and Heat and Mass Transfer	9		
Safety, health and environmental quality				
II			Industrial Safety	6
			Soil Mechanics	6
Processes and technologies for sustainable development				
II	Energy Systems	6	Soil Mechanics	9
Monitoring of the territory and mitigation of natural and anthropic risks				
II	Applied Geology	6	Soil Mechanics	9

Table 2.3 Third year Study Plan of Degree Course in Environmental Engineering

Year	1st Semester		2nd Semester	
	Teaching Course	**ECTS**	**Teaching Course**	**ECTS**
III	Hydrology and Hydraulic Structures	9	Environmental and Sanitary Engineering	9
	Elective Courses	12	Final Exam	3
Safety, health and environmental quality				
III	Traineeship	6		
	Energy Systems / Electrical Engineering*			12
	Environmental Management Systems and Quality Management Laboratory or** Renewable Energy Laboratory			15
Processes and technologies for sustainable development				
III	Water Resources Sustainable Management Laboratory			12
	Planning and Analysis of Impact in Urban Environment Laboratory or** Renewable Energy Laboratory			15
Monitoring of the territory and mitigation of natural and anthropic risks				
III	Multi-risk Analysis Laboratory			15
	Natural And Anthropic Hazard Mitigation Laboratory			12

***Mandatory elective course: students are requested to select only one between the two courses proposed.*

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