

An overview of the evolution of civil engineering education towards sustainability in Portugal

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Education is essential to prepare future professionals, preparing them for the labor market, by providing knowledge and practical experiences. The model that trains these professionals becomes crucial for professionals to adapt to the current needs of this market, which in itself is competitive and dynamic, so it is always in constant change of priorities and needs. It is undeniable that environmental and sustainability issues have become essential aspects in the performance of any business at a global level. Particularly, the concern with sustainability becomes evident in the field of civil engineering, due to the need of optimization of use of resources (raw materials, energy and water), that can have a huge impact on the environment, resulting both from reduction of consumption of resources, and pollutants emissions. Therefore, the MSc courses should have two levels of education on sustainability: at the multidisciplinary level, Higher Education schools should offer courses specifically dedicated to sustainable development and sustainability should be analysed globally; at the disciplinary level, each course should include the basic related concerns with sustainability issues. This work surveys civil engineering courses in Portugal

and analyzes how subjects related to SDGs are directly or indirectly present in the respective curricula.

Keywords: Good education practices; Indicators for sustainability; Pedagogical models; Sustainable cities; Sustainable projects; Teaching methodologies.

1. Introduction

Sustainability is one of the most discussed topics today, not only because of environmental concerns, but also because of social and economic aspects. In the present year (2022), when concerns related to the COVID-19 pandemic begin to fade and an ongoing outbreak of monkeypox is rising, the world is witnessing a war that affects not only countries directly involved, but the entire world, as it faces an unprecedented energy and food crisis. As such, it is necessary for society to find solutions that not only allow reverting the effects of this crisis, such as inflation, but also equipping professionals from the most varied areas to solve the challenges they face during their professional career.

The Portuguese education system is regulated by the Basic Law of the Educational System and is developed at three levels: elementary school, high school, and higher education.

In basic education, students are taught with different subjects and themes that prepare them to access secondary education. In secondary education, up to the ninth grade, students learn transversal subjects, from Portuguese and foreign languages, mathematics, science and social subjects. After completing the ninth year, students choose between several branches of education, whose teaching guides each student to learn the basic and preparatory themes of each profession. At the same time, there is vocational education whose themes and subjects that students learn focus more on the practical side, serving as the last step before students enter the job market. Those who complete the twelfth year of education, can choose to enter higher education and proceed their studies or to enter in the working market.

The last level of education is organized in a binary system that integrates university education and polytechnic education, and is taught in public and private institutions. Private higher education establishments obtain prior public interest recognition from the Government [1]. These institutions (universities/polytechnics and faculties) allow students to deepen their theoretical and/or practical knowledge about the future profession they intend to pursue. Some professions, such as Engineering, are subsequently regulated by professional associations, which carry out the self-regulation of professions whose exercise requires functional technical autonomy and independence, as well as technical ability [2].

In the case of Civil Engineering, a profession very focused on constructions, the higher education institutions are responsible for training professionals who should

have in mind the increase in construction efficiency, structural and thermal behavior, and reduction of the impact of the activity on the environment. Specifically, buildings are a key component in the design of cities, being infrastructures that house people at a global level, from the performance of their professions to their home on a personal level. This sector is estimated to provide 5 to 10% of employment in the country and generate between 5 to 15% of gross domestic product [3]. Also, Civil Engineering is an area that specialists are involved in many important sectors in society, from housing construction, dimensioning and construction of vital infrastructure such as drinking water supply, wastewater drainage and highly complex structures, such as bridges and airports.

There is also evidence that there is a synergy between buildings and public health. It is important to emphasize that the built environment is responsible for high energy consumption, large amounts of greenhouse gas emissions, considerable amounts of waste generation, as well as the use of large amounts of natural resources [3].

Given the numbers presented, higher education institutions must train future engineers with knowledge and techniques, figured in a competent, professional study plan with a theoretical, practical and scientific basis in order to mitigate and solve challenges in technical issues that influence society, the environment and economy.

Thus, it is worth analyzing how the issues related to the SDGs are directly or indirectly present in the respective curricula of the courses. The present work makes a survey of Civil Engineering courses in Portugal. The work does not infer the deepness of the contents of each specific course, as it would be a very extensive work, at this stage.

2. Sustainable Development Goals (SDGs) in education

As part of the 2030 Agenda for Sustainable Development, the Education 2030 Agenda, contributes to the right to an education of value, which is based on the principles of equality among all citizens. In addition to *Sustainable Development Goal 4 – Quality education*, which substantiates the aforementioned principle, States adopted the Education 2030 Framework for Action [4]. This document was adopted by 184 UNESCO Member States on 4 November 2015 in Paris. It is the result of a collective effort involving in-depth, wide-ranging consultations driven and owned by countries, and facilitated by UNESCO as well as other partners. The content ensures inclusive and equitable quality education and promotes lifelong learning opportunities for all [5]. For the aforementioned Sustainable Development Goal (SDG) 4, some targets and indicators were outlined by the United Nations [6].

In the specific case of this study, the focus is especially on goal 4.7, aiming at teaching sustainability and its main values. As such, the UN has defined the three pillars of sustainable development, which give shape and content to sustainable learning, namely:

- Society – understanding educational institutions and the role they play in change and development, as well as in democratic and participatory systems that provide the opportunity to express opinions, elect governments, create consensus and resolve disputes;
- Environment – awareness of resources and the fragility of the physical environment and the effects of human activities and decisions on the environment, with a commitment to include environmental issues in the elaboration of social and economic policies;
- Economy – awareness of the limits and potential of the economic growth and its impacts on society and the environment, with the commitment to reduce the levels of individual and collective consumption, in relation to the concern for the environment and social justice.

These three elements assume a dynamic process that is constantly changing and updating, recognizing that human society is in constant transformation. That said, sustainable development seeks to know the trends and implications of change [7].

3. Education in Civil Engineering towards sustainability

Education is the main agent of transformation towards Sustainable Development, increasing people's ability to transform their vision of society into reality. Research has shown that the majority of educators work to help individuals increase their intellectual, emotional and spiritual capacity, resulting in a maximization of prospecting in any socio-environmental or socio-cultural context in which it finds itself [7]. It is in this direction that future engineers must be educated.

In order to analyze the data, it is important to summarize what each university degree corresponds to. A Bachelor's degree (BSc) corresponds to 180 ECTS, which normally translates into 6 semesters, which totals three academic years of teaching/learning. An Integrated Master (iMSc), usually, corresponds to five years of study. The Master programs (MSc) is a second cycle of studies, and typically include four semesters and 120 ECTS. The Doctoral programs (PhD) in general, and there may be exceptions, corresponds to 240 ECTS. The PhD it's very focused on the area of specialization, so normally a large portion of the degree is dedicated to the development of the thesis.[8].

According to the data provided and research carried out, currently in Portugal there are 19 Degrees, 14 Masters and 6 Integrated Masters with a degree in Civil Engineering [9].

Regarding the BSc, and analyzing the study plan, it is possible to verify that there is a transversal similarity between the subjects taught, from Mathematics (e.g., algebra and derivations from the mathematics segments), Physics, Technical Drawing, Statistics, Management, and Economics, with a strong component focused on science applied to Civil Engineering, namely, subjects of Structural Calculation of Infrastructures, Strength of Materials, Geotechnics and Hydraulics. At the same

time, it is possible to verify that in this type of academic degree there are few or no themes related to sustainability and the environment, with some curricular plans having a subject related to Quality, Environment and Safety, Basic Sanitation or Quality and Economy in Construction. It should be noted that these topics previously mentioned are not combined in the same study plan of a university but registered separately through the analysis of several study plans, so it is noted that there are study plans from several universities where none of these topics is taught.

In the case of the Masters (MSC) and Integrated Masters (iMSC), it is possible to register a paradigm shift, so that in almost all study plans there is at least one course associated with Sustainable Development (sustainability), as shown in Table 1.

Table 1: Courses related to Sustainable Development in MSc and iMSc study plans.

Grade	School	Course
MSC	P.I. Castelo Branco	Civil Engineering -Sustainable construction: The entire study plan has a very strong focus on sustainability.
MSC	P.I. Coimbra	Civil Engineering: Building Envelope Technology; Sustainability and Urban Rehabilitation; Rehabilitation and Reinforcement of Buildings; Pathologies, Inspection and Diagnosis.
MSC	P.I. Leiria	Civil Engineering: sustainable construction; Safety and quality in works and projects; Environmental comfort in buildings; pathologies and rehabilitation in a built environment.
MSC	P.I. Lisboa	Civil Engineering - Buildings/ Structures: Territory and Environment Planning; Technology of Construction and Building Systems; Rehabilitation of Buildings; Inspection and Diagnosis of Building Anomalies. -Hydraulics: Technology of Construction and Building Systems; Rehabilitation of Buildings; Water and Wastewater Treatment Systems; Rehabilitation of Buildings; Inspection and Diagnosis of Building Anomalies. -Hydraulics: Technology of Construction and Building Systems; Rehabilitation of Buildings; Water and Wastewater Treatment Systems; Rehabilitation of Buildings; Inspection and Diagnosis of Building Anomalies. -Communication routes: Technology of Construction and Building Systems; Rehabilitation of Buildings; Rehabilitation of Buildings; Inspection and Diagnosis of Building Anomalies; Sizing and Rehabilitation of pavement.
MSC	P.I. Porto	Civil Engineering - Civil Constructions: Conservation and Rehabilitation of Buildings, Thermal and Acoustic Comfort of Buildings; Sustainable construction; Facade Technology. -Structures: Conservation and Rehabilitation of Buildings, Facade Technology. -Construction Management: Conservation and Rehabilitation of Buildings, Facade Technology; Quality Management in Construction; Construction Law and Insurance. - Infrastructures: Conservation and Rehabilitation of Buildings, Facade Technology. - Sustainable Energies: The entire study plan has a very strong focus on sustainability.
MSC	P.I. Viana do Castelo	Civil Engineering and Environment: Sustainability in Construction; Environmental management; Rehabilitation of Buildings; Sustainable Buildings.
MSC	P.I. Setúbal	Civil Engineering: Conservation and Rehabilitation I; Conservation and Rehabilitation II; Quality and Economy in Construction.

Grade	School	Course
		- Building Conservation and Rehabilitation: Conservation and Rehabilitation I; Conservation and Rehabilitation II; Thermal and Acoustic Rehabilitation of Buildings; Policies and Incentives for Urban Rehabilitation and Regeneration; Science, Technology and Degradation of Materials; Sustainable Construction and Technological Innovation.

Table 1: Courses related to Sustainable Development in MSc and iMSc study plans (cont).

Grade	School	Course
MSC	P.I. Setúbal	Civil Engineering: Conservation and Rehabilitation I; Conservation and Rehabilitation II; Quality and Economy in Construction. - Building Conservation and Rehabilitation: Conservation and Rehabilitation I; Conservation and Rehabilitation II; Thermal and Acoustic Rehabilitation of Buildings; Policies and Incentives for Urban Rehabilitation and Regeneration; Science, Technology and Degradation of Materials; Sustainable Construction and Technological Innovation.
MSC	P.I. Viseu	Civil Engineering - Construction and Rehabilitation Engineering: Durability and Rehabilitation of Reinforced Concrete Structures; Pathology and Rehabilitation of Buildings; Energy Efficiency and Comfort in Buildings; Management and Assessment of Quality, Environment and Heritage.
MSC	U. Algarve	Civil Engineering - Structures: Conservation and rehabilitation I; Conservation and rehabilitation II; Construction quality and economy. - Civil constructions: Conservation and rehabilitation I; Conservation and rehabilitation II; Construction quality and economy; sustainable construction and technological innovation; thermal and acoustic rehabilitation of buildings.
MSC	U. Madeira	Civil Engineering: Construction Technology.
MSC	U. Nova de Lisboa	Civil Engineering: Hygrothermal Rehabilitation and Optimization; Coating Technology; Construction Pathology; Rehabilitation of Buildings; Reinforcement and Repair of Structures;
MSC	U. Trás-os-Montes e Alto Douro	Civil Engineering - The study plan is not available online.
MSC	U. Fernando Pessoa	Civil Engineering - sustainable construction; environmental quality of buildings; impact assessment; building rehabilitation project; thermal, acoustic and ventilation project.
MSC	ULHT - Lusófona	Civil Engineering: Construction Conservation and Rehabilitation; Construction Quality and Sustainability; Planning and Management of Water Resources (optative specialization).
iMSC	U. Beira Interior	Civil Engineering: - General: Construction Materials I, Construction Materials II; Construction Technology. - Structures and Construction: Hydrology and Water Resources; Construction Materials I, Construction Materials II; Construction Technology; Construction Pathology; Assessment, Quality and Rehabilitation of Buildings; Durability of Building Materials; Building Systems Technology. - Geotechnics and Environment: Environmental Geotechnics; Environmental sanitation; Hydrology and Water Resources; Construction Materials I, Construction Materials II; Construction Technology; Construction Pathology; Assessment, Quality and Rehabilitation of Buildings; Durability of Building Materials; Building Systems Technology.
iMSC	U. Porto	Civil Engineering - Structures and geotechnics: Circular Construction; - Civil Constructions: Construction Quality; Environmental and Building Acoustics; Circular Construction; Wood Constructions; Building Thermal;

Grade	School	Course
		<ul style="list-style-type: none"> - Territory planning and transport: Urban Environment Quality Planning; Urban and Metropolitan Policies; - Hydraulics, water resources and environment: Sustainability and Climate Change; Treatment, Reuse and Desalination; Management of Water Resources and Protected Areas. <p>(students have the option to choose an optional course from any second cycle program, and may opt for a course associated with sustainability)</p>

Table 1: Courses related to Sustainable Development in MSc and iMSc study plans (cont).

Grade	School	Course
iMSC	U. Aveiro	Civil Engineering: Pathology of Constructions; Construction Conservation and Rehabilitation; Environmental Planning; Environmental Impact Assessment; Energy Efficiency and Thermal Comfort; Sustainable Water Management in Buildings; Materials and Sustainability; Urban Rehabilitation Policies; Sustainable construction.
iMSC	U. Coimbra	<p>Civil Engineering</p> <ul style="list-style-type: none"> - Metallic and Mixed Construction: Sustainability and life cycle analysis of structures; Wood construction; Metallic Structures for Offshore and Renewable Energies; Quality Management and Certification; Project of Metallic Structures for Renewable Energy Systems; Rehabilitation and Maintenance of Buildings; Thermal, acoustics and lighting. - Acoustic and Energy Efficiency for Sustainable Construction: Thermal and Energetic Behavior of Buildings; Sustainable Construction and Materials; Strategies for Acoustic and Energy Rehabilitation of Buildings; Environmental and Urban Acoustics; Energy Simulation and Indoor Environment Quality(Specialization in Energy and Indoor Environment). - Building Rehabilitation: Sustainable Construction and Materials; Strategies for Acoustic and Energy Rehabilitation of Buildings; Principles of Intervention in the Built Space; Rehabilitation of Old Buildings; Rehabilitation of Old Structures; Rehabilitation of Facades and Roofs; - Urban Mobility Management: Transport and Environment Planning Models; Sustainable Urban Mobility Policies; Management of Conservation and Rehabilitation of Transport Infrastructures; Management of Sustainable Transport Modes Networks.
iMSC	U. Lisboa - IST	<p>Civil Engineering</p> <ul style="list-style-type: none"> - Construction: Sanitation; Masonry and Wood Structures; Environmental Impacts of Built Spaces; Pathology and Rehabilitation of Construction; Construction Materials I; Construction Materials II; Comfort and Energy in Buildings; Construction Life Cycle. - Structures: Sanitation; Masonry and Wood Structures; Rehabilitation and Strength of Structures; - Geotechnics: Sanitation; Masonry and Wood Structures; Environm. Impacts of Built Spaces; - Hydraulics and Water Resources: Sanitation; Masonry and Wood Structures; Environmental Impacts of Built Spaces; Treatment Facilities; Modeling and Planning of Water Resources; Urban Drainage and Pollution Control; Hydraulics and River Rehabilitation. - Urbanism, Transport and Systems: Sanitation; Masonry and Wood Structures; Environmental Impacts of Built Spaces; Planning and Management of Urban Mobility; Solid waste management; Conservation of Transport Infrastructures; Solid waste management;
iMSC	U. Minho	<p>Civil Engineering</p> <ul style="list-style-type: none"> - Cities, territory and transport infrastructure: Applied Hydrology; Introduction to Natural Materials; Road Management and Rehabilitation; Built Environment Quality; Local Climate Action Instruments; Sustainability of Transport Infrastructures. - Buildings: Conservation and Rehabilitation of Buildings; Introduction to Natural Materials; Zero-Carbon Buildings; Technological Innovation in Buildings; Quality, Safety and Environment

Grade	School	Course
		<p>in Construction; Conservation and Rehabilitation of Buildings; Sustainable construction; Energy Rehabilitation of Buildings; Durability of Materials; Advanced Building Materials.</p> <p>- Structures and geotechnics: Applied Hydrology; Introduction to Natural Materials; Road Management and Rehabilitation; Wood structures.</p> <p>- Hydraulics and environment: Environmental Hydraulics; Applied Hydrology; Introduction to Natural Materials; Road Management and Rehabilitation; Project in Hydraulics and Environment; Integrated Management of Water Resources; Water Treatment Technology; Water and Public Health; Water Reuse Technologies; Waste Management and Recovery; Innovation in Water Treatment Systems.</p>

Table 1: Courses related to Sustainable Development in MSc and iMSc study plans (cont).

Grade	School	Course
iMSC	U. Porto	<p>Civil Engineering</p> <p>- Structures and geotechnics: Circular Construction;</p> <p>- Civil Constructions: Construction Quality; Environmental and Building Acoustics; Circular Construction; Wood Constructions; Building Thermal;</p> <p>- Territory planning and transport: Urban Environment Quality Planning; Urban and Metropolitan Policies;</p> <p>- Hydraulics, water resources and environment: Sustainability and Climate Change; Treatment, Reuse and Desalination; Management of Water Resources and Protected Areas.</p> <p>(students have the option to choose an optional course from any second cycle program, and may opt for a course associated with sustainability)</p>

It should be noted that this research only looked into the Masters in the field of Civil Engineering. There are many other Masters, not belonging to that field, focusing on the main themes of sustainability mentioned above (Society, Environment and Economy), showing that this trend of educating future professionals, giving them the skills to work aiming at Sustainable Development is gaining terrain.

4. Conclusions

The objective of this paper was to analyse the Civil Engineering programs and courses of Portuguese Universities on the point of view of sustainability integration. For this purpose, the study plans of all Civil Engineering courses that are currently accredited and available for students to choose from were consulted.

It was possible to conclude that in relation to BSc degrees, there is a large gap in the introduction of themes/disciplines related to sustainability, and which are based on the three fundamental pillars: Society, Environment and Economy. It should be noted that with the increasing phenomenon of students dropping out of school, or the non-continuity of studies for the second cycle (MSc programs), a student who completes studies with a BSc degree can practice the profession of Civil Engineering, after completing the internship and being recognition by the Order of Engineers (OE) or Order of Technical Engineers (OET). Therefore, this kind of professional

will not have received appropriate education in the sustainability approach, and there may be gaps in the identification of potential opportunities to improve sustainability conditions in the most varied cases, as well as in their efficient application.

In the case of iMSc and MSc, it is possible to conclude that some Universities/Politechnic Institutes have strong study plans with a focus on sustainability, with this focus varying according to the different specializations chosen by the students. It is also possible to conclude that there are some institutions that can strengthen their educational offer in sustainability, including subjects focused on the environment, economics related to environmental and sustainable policies, as well as various sciences applied to sustainable practices in the most varied themes related to civil construction.

Acknowledgements

This work was financially supported by Base Funding – UIDB/04730/2020 of Center for Innovation in Engineering and Industrial Technology, Portugal, CIETI – funded by national funds through the FCT/MCTES (PIDDAC), Portugal; LA/P/0045/2020 (ALiCE) and UIDB/00511/2020 - UIDP/00511/2020 (LEPABE) funded by national funds through FCT/MCTES (PIDDAC).

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