SUSTAINABILITY IN CIVIL ENGINEERING EDUCATION

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ABSTRACT

Introducing sustainable development in the academic curriculum of engineers is a necessity related to international objectives. Civil engineering, one of the sectors which uses natural resources and energy, must contribute to search for innovative solutions to reduce the environmental impact of its projects. In addition, the optional standard for engineering education named sustainable development, is attached as an essential competence in the CDIO framework. This paper focuses on the integration of the sustainable development aspect into the civil engineering training at ESPRIT for every level of learning. It first presents the process of integrating sustainable development into the civil engineering curriculum based on CDIO standards. Secondly, we will detail pedagogical approaches and learning tasks used in courses. Finally, we conclude with recommendations and outlooks. This study, which is related to civil engineering education has firstly an important pedagogical impact thanks to the application of the 17 Sustainable development goals built by the United Nations in 2015 to make them a reality. Second, it presents a strong impact on society which is known through the return of professionals and their needs within the framework.

KEYWORDS

Sustainability, Civil engineering, Curriculum, learning tasks, Standards: 1, 2, 5, 6, 8

INTODUCTION AND BACKGROUND

Engineering is a profession focused on resource consumption and continuous development. In civil engineering, natural resources are excessively used, and high greenhouse gas emissions are released into nature (Junar E, 2022). Climate warming is one of the consequences of this phenomenon. So, the search for environmental and societal solutions is a duty of civil engineers.

In accordance with the CDIO standards (Malmqvist et al., 2020 a&b, 2022), sustainable development can be introduced in the education program.

Students in civil engineering participate in the challenge of sustainable development with the purpose of green solution for building to protect planet and give good life conditions. They play a pivotal role in the transition towards a sustainable society.

The first part of this paper will be dedicated to explain how sustainable development is introduced in the training program based on CDIO standards, the teaching methods used will be described. Finally, the main results will be discussed for further recommendations.

PROGRAM PHILOSOPHY

The academic education in civil engineering, at Esprit (School of Engineering), takes five years when pedagogic engineering is adopted. This method is based on the detection of generic skills collected after investigations of professionals which is carried out every five years to reform the curriculum in line with the needs of professionals.

Teams are working on investigations to prepare a survey and they contact professionals to see with them the most competences searched on the civil engineering. In this survey we collect also the recommendations of professionals for continuous improvement in both the short and long terms. Therefore, both quantitative and qualitative analyses give rise to the generic competency repository (Ajailia N et al., 2019) (Figure 1).

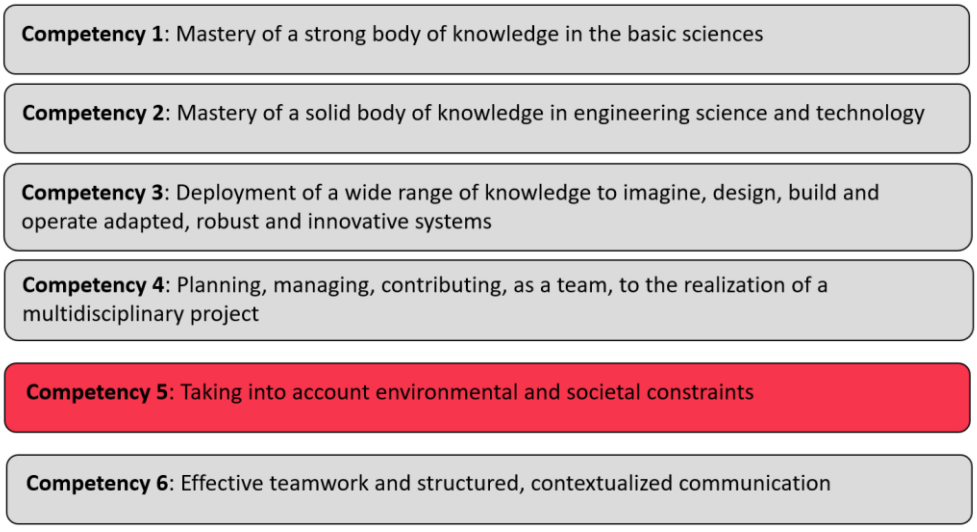

Figure1. Generic competency repository

The consideration of environmental and societal constraints is summarized on the fifth competency of civil engineers at ESPRIT. This generic competency is detailed in specific skills which subsequently give rise to the learning outcomes. This latter is thereafter divided into teaching units which are distributed on the different education levels.

In the engineering curricula, the sustainable development goals are incorporated for the development of future engineering education and help them to think about the environment and social issues (Gumaelius & Kolmos, 2020). So, module sheets are prepared when much information, such as learning outcomes module content and evaluation process, are summarized. All modules are affected to a responsible to follow permanent and temporary teachers and to make sure that the module content is respected. Teamwork and meetings can take place to answer questions or provide recommendations for teachers.

After each teaching module, students realize a lessons' assessment. They fill out a form online and the results are confidential. Teachers sensitize students to assist at this evaluation to have sufficient responses. The return of these evaluations is examined to improve the quality of teaching for the next years and students will be informed to complete the circle.

CURRICULUM IMPLEMENTATION

Specific skills which have emerged from the generic competence "Taking into account environmental and societal constraints" are (Ajailia N et al., 2019):
- Act as a responsible professional
- Be open and act ethically
- Self-assess your own work
- Position the company's actions in relation to environmental issues
- Position the company's actions in relation to social issues
- Apply occupational safety and health standards

These skills have been described as learning outcomes that have been combined to form teaching units. The integration of those units across civil engineering curriculum is presented in Figure 2 for integrated preparatory and Figure 3 for Engineering training.

S1	S2	S3	S4
LU Basic Mathematics 1	LU Basic Mathematics 2	LU Basic Mathematics 3	LU Basic Mathematics 4
LU initiation to documentary research	*LU Computational Mechanics*	LU Materials	LU Measurements and Topography
LU Urban Planning and Sustainable Development	*LU Introduction to Civil Engineering*	LU construction processes	*LU Associative & Collaborative Project*
LU Physics Chemistry	*LU Communication, Culture and Citizenship A1*	LU Mechanical	LU Applied Physics
LU Communication, Culture and Citizenship F1		*LU Communication, Culture and Citizenship A2*	*LU Communication, Culture and Citizenship F2*
		LU Internship 1	

Figure 2. The training plan for Integrated preparatory

S5	S6	S7	S8	S9
LU Applied Mathematics	*LU Data analysis*	*LU Digital Resolution Methods*	*LU Hydraulic*	*LU pathology and working conditions in Civil Engineering*
LU Applied Mathematics	LU Foundations & Supports	*LU Prestressed Concrete*	*LU Project management and management*	*LU New Technologies and Optimization*
LU Theory of Structures	LU Calculation and design of structures	*LU engineering works*	*LU Optional*	*LU Optional (project)*
LU Construction Technology	LU Management of the company	*LU Road & Hydrology*	*LU Project Structures & Structures*	*LU Law and regulations*
LU Homogenization	*LU Communication, Culture and Citizenship F3*	LU Internship *2*	*LU Communication, Culture and Citizenship F4*	*LU Preparation for working life*
LU Communication, Culture and Citizenship A3	*LU Building Structures Project*	*LU Communication, Culture and Citizenship A4*		LU Internship *3*

Figure 3. The training plan for Engineering training.

As seen in figure 2, the urban planning and development project is the first module introducing sustainable development in academic education of civil engineering. when students conceive the architecture of a space following the recommendations of high environmental quality. These aspects are generalized within the framework of the "Introduction to civil engineering" in which the students have the occasion to recognize the ecological structures.

In the second level, In the sustainable construction project and environment module students make models with ecological materials after studying the carbon footprint of standard building materials and compare them with ecological ones. The architectural aspect and sustainability approaches are the prerequisites of this unit taken from the first level of education. The students also prepare a good practice guide to justify the materials selected in their models. For the evaluation of this work, the coach evaluates the work progress during course sessions and finally, the method of pairs evaluation is used to engage students.

In the third level of education, the SDGs are taught to students who have completed the first cycle of training. The introduction to the SDGs was part of the homogenization module and aims to discover the framework of the goals set by the United Nations towards the end of 2030. The pedagogy adopted during this module was the project-based approach and the students were able to discover all the SDGs. The engineering student at this level has learned how to position himself in relation to what he has studied in terms of sustainable development and how he can apply the SDGs in the next modules as well as their contributions in engineering.

At the achievement of the third level, students select an option unit between four which is studied on the fourth and the fifth level of education. In table 1, the different modules of each option unit and hourly load of each one are presented.

Table 1. Modules of the different option unit

Teaching Unit		Semester 8 [19-20]	Load Hours Taught			ECTS	
Hydraulics		General Hydraulics	72	15	1	1	6
		Urban Hydraulics (Field Visit)		42	1	3	
		Roads and Miscellaneous Networks Project		15	2	2	
Project management and management		Construction Project Management (Site Visit)	81	30	1	3	7
		Intellectual Property Law		9	2	1	
		Innovation & Entrepreneurship		42	1	3	
Optional Teaching Unit	Structure	Structural Dynamics	114	42	1	3,5	10
		Stability of Buildings		30	1	3	
		Soils & Structures		42	1	3,5	
	Roads and bridges	Roads and interchanges		42	1	4	
		Bridges & Tunnels		42	1	4	
		Pathology and maintenance of roads and bridges		30	1	2	
	Eco-building and energy efficiency	Thermal regulation of buildings		42	1	4	
		Aeraulic installation of buildings		30	1	2	
		Eco-construction		42	1	4	
	Oil & Gaz	Reservoir Engineering		42	1	4	
		Drilling Engineering		42	1	4	
		Production Engineering		30	1	2	
Projet Structures & Ouvrages		***Projet Structures & Ouvrages***	39	39	1	4	4
Communication, Culture and Citizenship		Communication, Culture and Citizenship English	42	42	1	3	3
		Total	**348**			**30**	
		Load per week	**24,9**				

Among others, oil and gas option unit and Energy efficiency and Eco-building unit are prepared for civil engineering programs. These options'units contain three modules each one on the fourth level of education and one project for the fifth one.

In the oil and gas course, students study three optional modules (reservoir, drilling and production engineering). This unit is the basic production engineering course for civil engineering students who aim to initiate a career as a production engineer or assist on oil and

gas development projects. This course gives adequate competence to perform production facilities design and conduct production optimization.

The purpose of the energy efficiency is establishing an energy audit of the existing building and proposing solutions for improving the energy efficiency of housing or optimizing the design of new buildings. The Eco-building part treats the alternative materials of civil engineering, bio architectural design and the good practices of using natural research (energy and water).

For the first experience, the teaching method is based on the sharing of information with students, and they use the course for establishing a model which respects all setpoints.

In the last semester, students applied their sustainable development prerequisites to design and implement professional projects.

After the first experience of training with these options units, students see that full theoretical information is presented for the energy efficiency and Eco-building option and they didn't appreciate the evaluation method (model production). And for the oil and gaz option unit, they see that many mathematical equations can affect the student concentration.

The student's return is very well appreciated by a responsible. Teamwork takes place in searching for an effective solution. The idea is to combine the two options on only one named natural resources and energy efficiency (RN2E). This option unit contains different modules (table 2). Students work on the production of numeric models for the Eco-building module and digital simulation for the others.

Table 2. RN2E option unit on plan of education

Teaching Unit		Semester 8 [22-23]	Load Hours Taught			ECTS	
Hydraulics		General Hydraulics	72	15	1	1	5
		Urban Hydraulics (Field Visit)		42	1	3	
		Roads and Miscellaneous Networks Project		15	2	1	
Construction processes and environmental impact		Construction Project Management (Site Visit)	117	30	1	2	4
		Environmental impact of constructions		15	1	1	
		General Construction Processes		21	2	1	
Management		Intellectual Property Law		9	1	1	4
		Innovation & Entrepreneurship		42	1	3	
Optional Teaching Unit	Structure	Structural Dynamics	114	42	2	3,5	10
		Stability of Buildings		30	2	3	
		Soils & Structures		42	1	3,5	
	Roads and bridges	Roads and interchanges		42	1	4	
		Bridges & Tunnels		42	1	4	
		Pathology and maintenance of roads and bridges		30	1	2	
	Natural Resources and Energy Studies	Energy regulation of buildings		42	1	4	
		eco-construction		30	1	2	
		Natural ressources engineering		42	1	4	
Structures project		Structures project	39	39	1	4	4
Communication, Culture and Citizenship		Communication, Culture and Citizenship English	42	42	1	3	3
		Total	**342**			**30**	
		Load per week	**24,4**				

RESULTS AND DISCUSSION

The introduction of sustainability education in the program of civil engineering is not recent. It is outlined and well detailed previously (sterling, 2004; Kolmos et al, 2016). At the same topic, our experience details the results collected for forty years since including sustainability education in civil engineering programs.
The progress of academic training between the first and the final level shows a continuous implementation of sustainable development (Figure 4). For the development of each competence of engineering such as the fifth one (Taiking into account environmental and societal constraints which presented in Figure 1), modules of the first level play the role of the prerequisite for the higher one. In fact, to make their solution RN2E project, students use their prerequisites from previous years as shown in Figure 4.

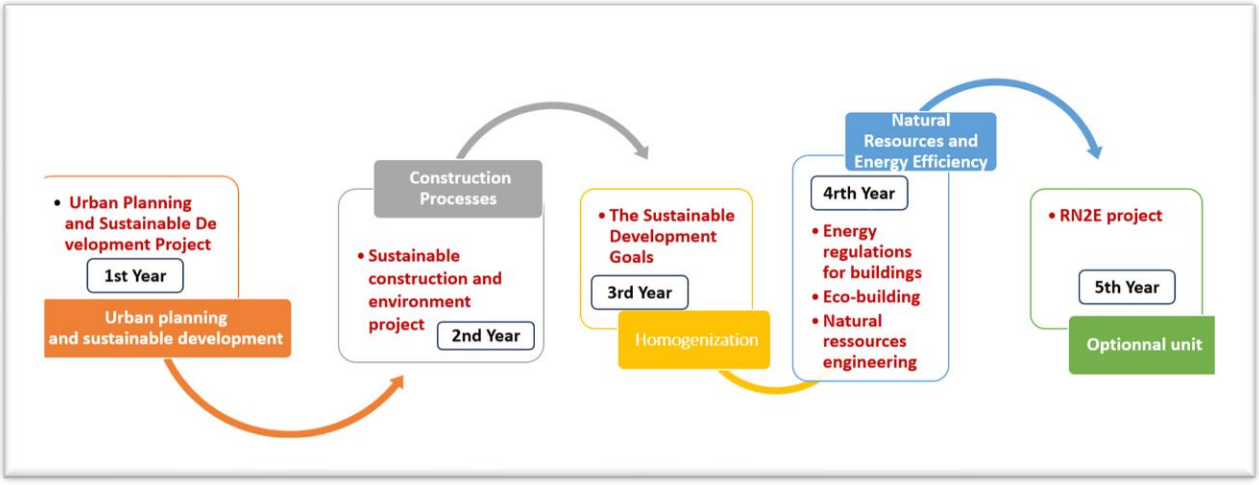

Figure 4. Prerequisite progress with the education level

Not only these prerequisites are used to develop the solution of each teamwork. Different numerical tools are used by students to concept their ideas. Artificial intelligence takes place also in the different work presented. It can also be shown that communication is very improved in teamwork and in the different expositions. Management of time and resources are also well-appreciated.

The combining units and the assessment methods are well appreciated by students. This fact is shown in the results of evaluation of lessons learned at the end of the improved unit. During the coaching sessions, teachers show an increase in motivation and autonomy of them. Professionals, who participate also on the study and coaching of Engineering training especially on the final level when studying the project appreciate the best practices used to improve the quality of education.

The exchange professionals-students are an occasion not only to share with them the professional experience but also to purpose internship and end-of-study internship.

On the same topic, and in the context of exchange, a seminar is also scheduled every year to sensitize students about the environmental problems. The first version, named Building of tomorrow, is focused on the ecological materials and the bioclimatic architecture. Engineers,

architects, professionals and academics explain the necessity of using local and green materials in construction. They presented their ecological projects to sensitize future engineers to develop their skills in the green buildings and open axes of research. On the second one, the engineer facing climate warming in Africa, African speakers participate in this event. Three different axes are presents: Drought and water management, Renewable Energy and finally Ecological materials and recycling. Students have understood that civil engineers must think about the environmental and societal constraints before construction and the necessity to introduce green energy and water management systems in the conception. On the third season, the committee think on the water problems and named this event The engineer facing the water crisis which takes place on April 2024.

These events are an opportunity for students to exchange with professionals and industrials, therefore, to understand the working environment and respect regulations and constraints in the national and international concept.

CONCLUSION

This paper shared a broad approach that can be used by Civil engineering program seeking to integrate sustainable development into its curriculum using the CDIO Framework. Civil engineering is a discipline that incorporates many aspects: technological, economical, societal, and environmental ones. The approach of sustainability integration in the educational program in civil engineering aims to provide the foundational digital, human and sustainable development of future engineers and to apply them in searching solution on the ground.

This study is in accordance with the conclusion from Rosen (Rosen et all, 2021), in which, he used the SD standards for guiding and evaluating program development on the one hand and for evaluating and enhancing the status of sustainability in engineer program on the other hand.

The introduction of building information modelling (BIM) in these modules is the next step. This academic innovation will begin the next academic year. We estimate it will take three years to complete all modules.

Finally, our recommendation revolves around the necessity to introduce sustainability for all academics and create a multi-disciplinary project to improve the engagement of each one on the problems of society.

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