

ASSESSING SDGS' LEARNING OBJECTIVES IN ENGINEERING EDUCATION. CASE STUDY. ENGINEERING IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT AT UPC BARCELONA TECH

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ABSTRACT

Education for the Sustainable Development Goals (ESDG) in higher education requires a methodology to diagnose its presence in the degrees as a starting phase to design a desired scenario, where graduates are qualified with the needed SDG competences. The EDINSOST2-SDG project, involving 8 Spanish universities, pursues this transition and sets the framework for this study.

This paper shows the methodology and results of diagnosing the presence of sustainability competences and the SDG at the undergraduate engineering degree in Industrial Design and Product Development at the School of Engineering of Vilanova i la Geltrú of the Universitat Politècnica de Catalunya. The methodology can be applied to any engineering degree and synthesises the results through Sustainability maps. The starting point is the Engineering Sustainability Map, from the project EDINSOST2-SDG that states the learning outcomes in relation to Sustainability and SDG that engineering students must master when graduating. From there we build assessment maps of the degree analysed. Map 1: shows the Sustainability learning outcomes. Map 2: shows the SDG based on their learning objectives. These maps allow curriculum designers to verify to what extent Sustainability and SDGs are embedded in the subjects, semesters and in the whole engineering degree.

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1 INTRODUCTION

1.1 The Agenda 2030 and higher education

In September 2015, the United Nations adopted the Agenda 2030 for Sustainable Development. The resolution announces a plan of action focused on «people, planet and prosperity» that seeks to «strengthen universal peace in larger freedom» and recognizes that «eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development». The 17 Sustainable Development Goals (SDG) and their 169 associated targets are meant to «balance the three dimensions of sustainable development: the economic, social and environmental» [1]. According to UNESCO, ESDG arises as an essential instrument to achieve the SDGs that allow to face current challenges such as Climate Change and the need of a global shift regarding values, attitudes and skills. UNESCO defined 255 learning objectives (15 for each SDG) that students should master. Focusing on the role of higher education in contributing to SDGs achievement, Universities have historically been institutions aimed at creating and transmitting knowledge through research and teaching. Therefore, integrating ESDG in higher education is considered a key component to foster the emergence of agents of change in our society [2]. Mapping what a university is already doing in relation to ESDG is the first strategic step to implement it in a degree [3]. Hence, this paper is aimed at finding how to diagnose the presence of sustainability and SDGs in a higher education degree.

1.2 EDINSOST2-SDG and the Engineering Design Degree at UPC

EDINSOST2-SDG is a project aimed at integrating SDGs into sustainability training in Spanish university degrees. It is financed by the Spanish Ministry of Science, Innovation and Universities (MCIU), the State Research Agency (AEI) and the European Regional Development Fund (ERDF). The project provides a set of tools that allow to diagnose the presence and learning of sustainability in a degree. The tools applied in this case study are the following:

A. Engineering Sustainability Map (ESM)

The ESM is a matrix containing a common Sustainability Map for all engineering degrees which summarizes the learning outcomes related to the 4 transversal sustainability competences proposed by the Conference of the Presidents of the Spanish Universities (CRUE) [4, 5] and the SDGs' learning objectives proposed by UNESCO [1, 2].

B. Sustainability Presence Map (SPM)

The SPM is a matrix that shows how a degree fulfils the learning outcomes of the ESM. Each cell relates each learning outcome proposed by the ESM to each subject that is being taught in the degree.

C. SDG Presence Map (SDGPM)

The SDGPM is a matrix that shows how a degree fulfils the SDGs based on the learning objectives of UNESCO [2].

The bachelor's degree in Industrial Design and Product Development Engineering is being taught at the UPC Engineering School of Vilanova i la Geltrú (EPSEVG). It is aimed at providing the student with the skills to become an industrial designer and product developer [6]. Figure 1 shows the curriculum of the degree including the specific optional subjects related to itineraries and also cross curricular electives.

Fig 1. Curriculum of the undergraduate degree in Industrial Design and Product Development Engineering.

DEGREE STRUCTURE

Semester 1	Semester 2	Semester 3
Chemistry Fundamentals of Mathematics Informatics Physics Sustainability and Accessibility	Aesthetics Graphic Expression Materials Science Mathematics for Design Physics II	Artistic Expression Design Workshop I Layout and Prototyping Mechanics Statistics
Semester 4	Semester 5	Semester 6
Business Design and Technical Representation Design Workshop II Elasticity and Strength of Materials Electrical Systems	Basic Design Computer-Aided Design Electronic Systems for Design Graphic Design Manufacturing Processes	Design Methodology Design Workshop III Mechanism Design Product Design Project Management
Semester 7	Semester 8	
Marketing and production Optional (24 ECTS)	Bachelor's thesis (24 ECTS) Optional	

Specific optional courses

User-Centred Design and Inclusive Design itinerary	Product Design and Manufacture itinerary
Human-System Interaction Inclusive and User-Centred Design Usability and Accessibility Engineering	Forensic Engineering and Industrial Reliability Design Materials Design and Prototype of Molds

Cross-curricular electives

Industry 4.0 itinerary	Teams itinerary	Social itinerary
Internet Cross-Platform and Distributed Programming Industrial Automation	Emobility Emobility Lab Agil	Applied Sustainability Applied Accessibility Social Robotics Workshop
Internationalization itinerary	All subjects worth 6 ECTS if not specified	
Writing Techniques for Engineering Academic and professional Communication Techniques Academic Skills for Project Development Language Practice (3 ECTS)		

The degree has a study load of 240 ECTS [7]. These are distributed in 60 basic education credits, 126 compulsory credits, 30 optional credits and a final degree

project worth 24 credits. 49 subjects, the final degree project and optional external internships configure each student's path in order to obtain the degree.

2 METHODOLOGY

This paper presents a case study that applies a methodology to evaluate the presence of sustainability and the SDGs in Engineering Degrees, using tools provided by EDINSOST2-SDG. The methodology is piloted as a case study to the Engineering Design degree taught at EPSEVG of the Universitat Politècnica de Catalunya.

2.1 Information sources

Gathering information about the degree is the very first step. For this case study, the following information sources have been considered:

- The latest version of the application form for modification of official degrees, which provides relevant data to understand the relation between subjects, and their corresponding competences [7].
- The latest versions of the teaching guides that are available in the degrees' official website, which offer information about the content, the methodology and the evaluation of each subject [6].

2.2 How to translate the information into maps

The starting point is the Engineering Sustainability Map (ESM), which states the learning outcomes in relation to Sustainability and SDG that engineering students must master when graduating. The map disaggregates the transversal competences in 4 dimensions (environmental, social, economic and holistic) that can be assessed to facilitate its understanding and implementation. The result is a map with 7 competency units that are operationalized through learning outcomes that students need to have when graduating. The learning outcomes are categorized through a specific taxonomy based on the simplified Miller Pyramid (Level 1: Know, Level 2: Know How and Level 3: Demonstrate + Do), useful for sequencing the acquisition of learning outcomes and ending with a total set of 53 learning outcomes for the 7 competency units. The ESM facilitates analysing how sustainability is being embedded in an engineering degree [5].

To apply the ESM in the Design engineering degree, we created a matrix that compares the 81 competences of the degree (columns) with the 53 learning outcomes (rows) proposed by the ESM. To evaluate the concordance between the competencies of the degree and the learning outcomes proposed by the ESM, a scoring criteria has been developed: "A" is scored if there is a lot of concordance between the meaning of the learning objective and the meaning of the competence, as well as some words coincide; "B" if the meaning of the learning objective can be easily related to the results of the competence; "C" if the meaning of the learning objective can somehow be related to the results of the competence. and "D"

otherwise. To complete the matrix, each cell needs to be scored according to the ESM scoring criteria (Table 1).

Table 1. ESM - Degree Competences matrix.

Applying the ESM to a degree		Competences of the degree		
		Competence 1	Competence ...	Competence n
ESM learning outcomes	Learning outcome 1	A, B, C or D	A, B, C or D	A, B, C or D
	Learning outcome ...	A, B, C or D	A, B, C or D	A, B, C or D
	Learning outcome n	A, B, C or D	A, B, C or D	A, B, C or D

Map 1: Sustainability Presence Map (SPM)

The first step is to relate the Sustainability learning outcomes defined in the ESM, to each subject of the degree. The result is a Sustainability Presence Map (SPM) of the degree. A complete SPM provides a visual representation of how sustainability competences are being distributed in a degree. To create the SPM of the Design engineering degree, we created a matrix that compares each subject of the degree (columns) to each learning outcome of the ESM (rows). This implies checking in advance which competences each subject is working on. Once the matrix is set, each cell can be scored 3, 2, 1 or 0 if the scoring in the ESM has been A, B, C or D, respectively. In case that a subject has competencies that coincide in scoring the same learning outcome, only the highest score will be taken into account.

Table 2. Completing the Sustainability Presence Map.

Completing the SPM		Subjects of the degree		
		Subject 1	Subject ...	Subject n
ESCM learning outcomes	Learning outcome 1	3, 2, 1 or 0	3, 2, 1 or 0	3, 2, 1 or 0
	Learning outcome ...	3, 2, 1 or 0	3, 2, 1 or 0	3, 2, 1 or 0
	Learning outcome n	3, 2, 1 or 0	3, 2, 1 or 0	3, 2, 1 or 0

To translate the SPM score into percentage, it is necessary to consider the operationalisation of the ESM. This is possible by applying the Eq. (1) in each cell of the SPM. The resulting percentage shows the presence of each learning outcome in each subject.

$$SPM[\%] = \frac{100 * SPMscore}{nDIM * nCU * nL * nLO * nPr} \quad (1).$$

Where:

SPMscore: cell score in the SPM; **nDIM:** number of possible dimensions of a competence; **nCU:** number of competency units related to the dimension; **nL:** number of learning levels related to the competency unit; **nLO:** number of learning outcomes related to the level; **nPr:** amount of possible results according to the SPM scoring criteria. Scoring 0 will always mean a 0% of presence. Therefore, it is not considered as a possible result that distributes weight of the percentage.

Map 2: SDG Presence Map (SDGPM)

A SDGPM is a matrix set for each subject of the degree that shows the presence [%] of each SDG (columns) in relation to each learning outcome (rows). To obtain a SDGPM, first the EDINSOST2-SDG project identified which of the UNESCO SDG learning objectives should be mastered in any Engineering Degree and second, it related those to the learning outcomes of the ESM. Knowing both relations allows us to create a matrix that states the percentage of each learning outcome in relation to accomplishing each SDG. To calculate the presence of each SDG in a subject, the percentage of presence of each SDG related to a learning outcome has to be multiplied by the percentage of the SPM [%] of the corresponding learning outcome. Final step is taking the maximum value [%] of each SDG column, which will represent the presence of a SDG in a subject.

3 RESULTS

Results are synthesized in a graphical format to ease the communication of the diagnosis outcomes. Spider charts show which competences, learning outcomes or SDG are covered at degree, semester or subject level. Visualizing the strengths and weaknesses of sustainability and SDGs content in a degree should raise awareness of which aspects could be improved in a curriculum. A degree-level diagnose highlights which are the less (or most) aspects assessed in a degree. The results should help rethinking the distribution of the subjects to make the degree more efficient. Knowing the diagnose of a specific subject provides hints on which competencies could be further developed and therefore enhancing the whole degree's results. Figures 2 to 4 are examples of the results that can be obtained.

Figure 2 represents the average percentage of the presence of the 4 sustainability competencies proposed by CRUE in the whole degree. Competence 1 (C1) stands out above the other 3, while competence 3 is the least developed. Figure 3 represents the average percentage of the presence of the 7 Competency Units (CU) of the ESM proposed by EDINSOST2-SDG in the 6th semester of the degree. Semesters 1 to 5 appear in grey as background to visually compare them to semester 6. Results show how Competency Unit 1 (CU1) and Competency Unit 7 (CU7) obtain the highest percentages while the rest of CU show a lower presence.

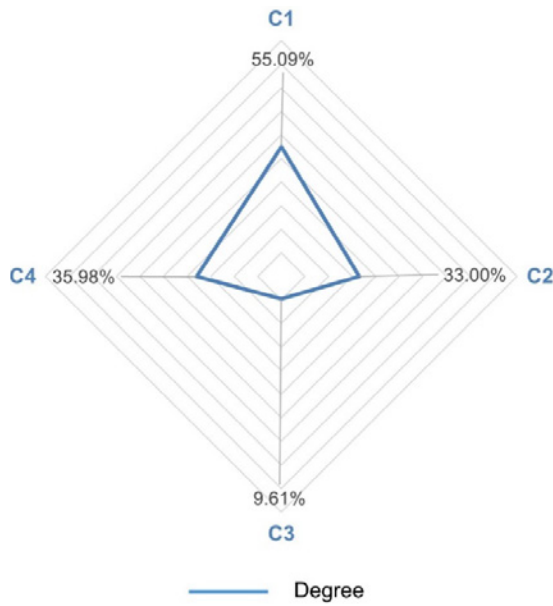


Fig. 2. Sustainability Presence Map in the whole degree in relation to the 4 sustainability competencies of CRUE [%].

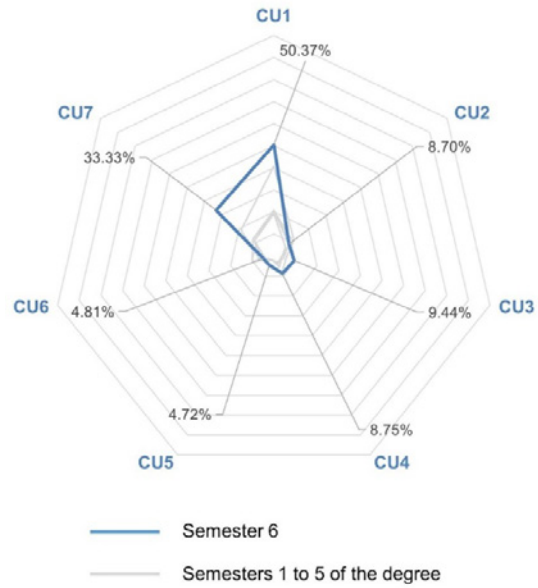


Fig. 3. Sustainability Presence Map of the 6th semester visually compared to semester 1 to 5 in relation to the 7 Competency Units (CU) of the ESM [%].

Figure 4 and 5 represent the average percentage of the presence of the SDG learning outcomes that were considered adequate to be addressed through any engineering degree, according to the EDINSOST2-SDG criteria. SDG2, SDG14 and SDG15 were not considered to be common SDG among all the engineering degrees but where included anyways bearing in mind that SDGs are indivisible and interrelated. Results show, for instance, how SDG7, SDG9 and SDG12 may have room for improvement, considering their close relation to Product engineering.

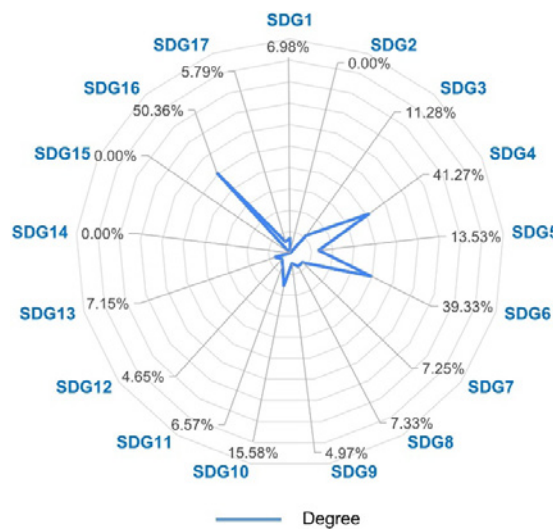


Fig. 4. SDG Presence Map of the degree in Design engineering [%].

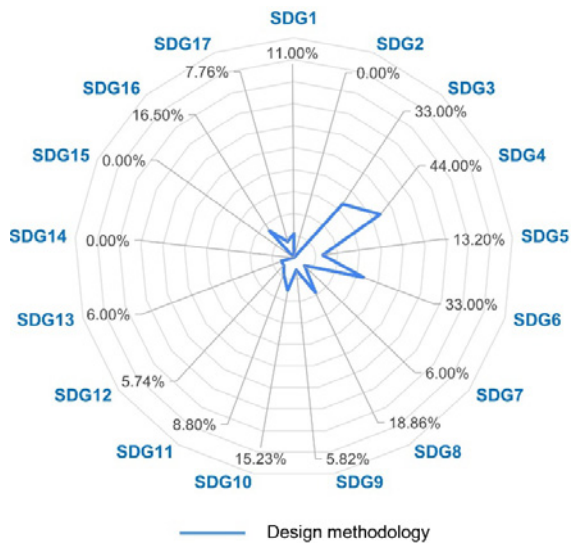


Fig. 5. SDG Presence Map of the Design methodology subject [%].

4 SUMMARY AND ACKNOWLEDGMENTS

We have introduced a methodology to analyse how sustainability and SDG are embedded in engineering degrees. Using Sustainability Presence Maps with graphical tools shows to which extent sustainability and SDGs are embedded in each course, semester and in the degree. The methodology has been applied to the Engineering Degree of Design at the EPSEVG of the UPC.

The results obtained are useful to consider which aspects of the curriculum may be sensitive to improvement and also to detect how sustainability is being approached in a degree, semester or subject.

When representing the data by degree or semester, it has been noted that it is challenging to include the optional subjects. Those should be included in diagnoses focused on assessing the different paths that the degree offers. A further limitation of the project is related to the information sources. Official documentation is not always updated and some competencies did not coincide with the information presented in the teaching guides. Further research should develop an analysis by using other information sources. The project Edinsost2-SDG is already working on this aspect and has developed a questionnaire to faculty and students which will be piloted through a similar methodology.

The concept “presence” used when considering the presence of the sustainability competencies, refers to the percentage of accomplishment of the learning outcomes of the ESM proposed by EDINSOST2-SDG. A degree would very rarely score a 100% of presence but the methodology offers results that expose which competencies are being prioritized and which not. This implies helping curriculum designers to detect gaps and opportunities. On the other hand, the concept “presence” used when analysing the presence of the SDGs is related to which SDG learning objectives are related to the ESM. In the same direction of what has been commented, the value of conducting such an analysis is creating a framework to guide further improvements in a degree.

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