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Strategic implementation of education for sustainable development within the industrial engineer curriculum

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Abstract

The main objective of this presentation is to validate a methodology to address education for sustainable development within the industrial engineer curriculum that will define the content, skills and learning methods in a process of continuous improvement and compatible with the national curriculum regulations for the Bachelor and Master of the IQS School of Engineering.

In order to validate the teaching methods and their implementation the stakeholders, industry, public authorities and academia has been asked. A previous research has set the survey content. The results had determined the main skills to develop their work, to what extent have these skills the new graduates, and the areas we should consider now to move towards a sustainable development.

The questions to the experts were set in three groups. In the first group of questions they asked to assign the order of relevance to the categories: Environmental aspects, Resources scarcity, Social Impact, Cultural & Values aspects, Future generations, Unbalances, Technology, Economical aspects, Educational aspects, Actors and stakeholders to advance towards sustainable development.

In the second part of the survey the experts had decided the relevance of related competencies, to prepare graduated people to the demands of the professional market and the level the graduate achieve on these competencies.

The third question group was related to the curriculum and how must be the sustainability criteria be included within the engineering curriculum (degree + master). There are defined three options: 1) embedded the sustainable concepts in the subjects, 2) show recent real cases, 3) develop projects.

The panel of experts has been composed by public authorities of the administration and professional institutions, senior Engineers, IQS engineers and multidisciplinary experts.

Finally, the survey's conclusions have been applied in the curriculum in concordance with the Project P-15 Environmental Sustainability IQS of 2017-2020 Strategic Plan and the ABET Program accreditation

1 Introduction

This research was conducted for the curriculum in industrial engineering within the framework that defines the implementation of the Bologna Declaration on Higher Education in Spain. It was developed for the Bachelor and Master's degree program in Industrial Engineering at IQS School of engineering, federal member of the University Ramon Llull (URL). Both engineering programs are following the ABET Program accreditation.

The students of the Industrial Engineering B. Eng. must complete the ECTS credits of the program of studies distributed as follows: 212 Required, 10 Elective, 6 Practicum and 12 Final Degree Project. According to the Spanish regulations (Decree CIN/351/2009, of 9 February), the different credits are distributed among the following modules:

Table 1: Distribution of credits of the Industrial Engineering B. Eng.

Categories	Description	ECTS	TERMS
M1	Basic Formation	60	1-2
M2	Core Topics of Industrial Engineering	66	3-7
M3	Specific Technology	78	3-8
M4	Professional Skills	24	5-8
TFG	Final Degree Project	12	8

It should be noted the cross-disciplinary of content taught in the program, covering different areas of engineering as required by legislation in Spain. It is mandatory to obtain professional skills as an engineer and to keep a close link with the needs of the industry. The Bachelor degree enables access to the official studies of the Master, as provided Royal Decree RD 1393/2007, of 29 October, which establishes the planning of official university education.

All students registered in the Industrial Engineering MS program (*Plan 2012*) take **120** credits divided into two academic years. These 120 credits are distributed in 60 credits required *(Obligatorias,* R: Required), 30 credits electives (*Optativas*, E: Elective), 14 of there are electives form specialization (*Optativas de especialidad*, SE: Selected Elective) and 30 credits that corresponds to the Master's Thesis.

In summary, it can be described that the Bachelor and Master‘s degree qualifies to design, develop, implement, improve, solve and manage systems, products and processes in various industrial fields and in interdisciplinary teams, and to communicate knowledge and conclusions in an environment sustainable and responsible, and organizing and planning projects and human teams.

All this thanks to the skills acquired that allow graduates know and apply knowledge of science and technology to engineering practice, understand the impact of engineering on the environment and sustainable development of society, incorporate new technologies and engineering tools in their professional activities and ability to generate new ideas, among others

The analysis of the Spanish degree and Master, its regulations and outcomes, and analysis of the learning styles of our students, permit develop a proposal for embedding sustainability in the industrial Engineering curriculum according to the learning styles of actual students as individuals. (De Graff, E, 2006) (Wals, A.E.J.2014)

The IQS School of Engineering is developing the IQS 2017-2020 Strategic Plan. There have been defined four Strategic pillars. The P-15 Environmental Sustainability IQS is included in the pillar named “Comprehensive training and social and environmental compromise”.

The Project’s objectives are to continue to increase of the sensitivity of IQS for ecology and sustainability, in order to achieve an institution committed to sustainability and the environment in the framework of the objectives pursued by the global project HEST – High Education for Social Transformation, which essentially proposes what should be the contribution of Universities to help transform society.

2 Objectives

The main objective of this presentation is to validate a methodology to address education for sustainable development within the industrial engineer curriculum that will define the content, skills and learning methods in a process of continuous improvement and compatible with the national curriculum regulations for the Bachelor and Master of the IQS School of Engineering.

In order to validate the teaching methods and their implementation the stakeholders, industry, public authorities and academia has been asked. A previous research has set the survey content. The results had determined the main skills to develop their work, to what extent have these skills the new graduates, and the areas we should consider now to move towards a sustainable development.

Finally, the survey's conclusions would be applied in the curriculum in concordance with the Project P-15 Environmental Sustainability IQS of 2017-2020 Strategic Plan and the ABET Program accreditation (Leal Filho et al. 2019)

3 The Survey development

The survey was conducted in the first half of 2017. An expert panel of employers, representatives and academy members, teachers and management positions was mailed. Thirty responses were received from the 50 requested. In the first part of the survey they were asked to indicate their current position, their degree and the year of graduation. Table 2 shows the percentages of responses according to the year of graduation.

Table 2: Distribution of responses based on graduation year

Elapsed from graduation	Graduation year	Percent
< 10 years	2010-2019	15,38%
10 a 20 years	2000-2009	30,77%
20 a 30 years	1990-1999	23,08%
30 a 40 years	1980-1989	19,23%
> 40 years	- 1979	11,54%

Since a validation was sought to be able to implement within the curriculum of the industrial engineer itis important to indicate that the majority of professors in the industrial department and the teaching managers (80%) were obtained.

The survey was organized into three parts with the aim of answering the following three questions. What should be done? What skills are required? and how should they be included in the curriculum?

3.1 What should be done? Actions to advance towards a sustainable development

In the first group of questions they asked to assign the order of relevance to the categories: Environmental aspects, Resources scarcity, Social Impact, Cultural & Values aspects, Future generations, Unbalances, Technology, Economical aspects, Educational aspects, Actors and stakeholders to advance towards sustainable development. (Segalàs, Ferrer-Balas, and Mulder 2008)

Table 3: The categories to advance towards sustainable development in order of relevance

Categories	Description	Average
1	Environmental aspects	8,3
2	Resources scarcity	7,83
3	Social Impact	6,6
4	Technology	6
5	Education aspects	5,47
6	Unbalances	4,77
7	Future generations	4,43
8	Cultural & Values aspects	4,33
9	Economical aspects	3,87
10	Actors and Stakeholders	3,4

Table 3 results shows that it is considered essential take care of the environmental aspects and the scarcity of natural resources being the less important the economic aspects and those of agents and employers. In an intermediate position we find social impact, technology and education aspects strongly related to the university.

3.2. Which skills are required? Study of the related competencies and the level the graduate achieve on these competencies

In the second part of the survey the experts had decided the relevance of related competencies, to prepare graduated people to satisfy the demands of the professional market and the level the graduate achieve on these competencies.

The Catalan Agency for University Quality (AQU) collects the results from all the Catalan universities and produces a public report. The current report is in preparation. The survey carried out includes information about the graduate's profile, the skills and competences acquired, the personalized attention and the facilities and services. Its main goal is obtaining valuable information for the evaluation, being coherent with the Educational Objectives (AQU 2014). For future research, the content of the survey used the competency structure set out in the AQU Studies.

The experts had to evaluate from 1 to 5 the skills defined by the importance they have for an engineer in the development of their work and then they had to answer to what extent the recent graduates have these competencies. The position 1 indicated the less important and the skills not acquired, as well as the position 5 defined the most important and the best acquired. Table 5 shows the percentage in each position.

The competences with higher percentage were "Develop and structure ideas and proposals in a creative way and with critical reasoning" (57,69%), "Manage the new situations". "Develop technical projects considering the impacts, risks and social and the environment" (50%) and "Demonstrate an understanding of the importance of professional ethics and the consideration of all parties involved" (50%)

In the other hand "Know the strategies to minimize the environmental and social impacts of a project" (15,38%). "Communicate ideas and efficient proposals related to sustainable development". (15,38%) and "Manage the new situations". (19,23%) are considered of little importance

Taking account to the difference between how important is considered a competence with the extent that the recent graduates have acquired competences the biggest differences are in " Know the strategies to minimize the environmental and social impacts of a project"(a difference of -76,93%)"Manage the new situations." with a difference of -69,24% i "Develop and structure ideas and proposals in a creative way and with critical reasoning" with a difference of -61,41%

The competence "Demonstrate an understanding of the importance of professional ethics and the consideration of all parties involved "is the one with less differenced with a 23,08%

Table 5. Competencies for sustainable development (1. Nothing important and nothing acquired, 2. Little important and little acquired, 3. Slightly important and slightly acquired, 4. Quite important and quite acquired, 5 Extremally important and extremally acquired.

		1	2	3	4	5
Disciplinary contents	1. Have acquired advanced knowledge that allow to understand the challenges of sustainable development related to the practice of engineering.	0,00 0,00	0,00 19,23	15,38 50,00	65,38 30,77	19,23 0.00
	2. Consider knowledge of different engineering disciplines to achieve objectives of sustainable development in the practice of engineering.	3,85 15,38	3,85 34,62	15,38 26,92	50,00 23,08	26,92 0,00
Cognitive outcomes	3. Use an approximation holistic and systematic to explore solutions to complex problems.	3,85 3,85	0,00 19,23	26,92 53,85	50,00 23,08	19,23 0,00
	4. Develop and structure ideas and proposals in a creative way and with critical reasoning	0,00 0,00	0,00 19,23	3,85 46,15	38,34, 34,62	57,69 0,00
	5. Know the strategies to minimize the environmental and social impacts of a project	0,00 3,85	0,00 19,23	7,69 61,54	69,23 15,38	23,08 0,00
	6 Develop technical projects considering the impacts, risks and social and the environment	0,00 3,85	0,00 11,54	3,85 46,15	46,15 38,46	50,00 0,00
Personal Management outcomes	7. Manage the new situations.	0,00 11,54	0,00 19,23	11,54 50,00	34,62 19,23	53,85 0,00
Instrumentals outcomes	8. Communicate ideas and efficient proposals related to sustainable development.	0,00 3,85	3,85 34,62	30,77 46,15	50,00 15,38	15,38 0,00
Interpersonal outcomes	9. Working with others as members of a multidisciplinary team with opinions that do not have to coincide with the own.	0,00 0,00	0,00 23,02	3,85 34,62	57,69 42,31	38,46 0,00
	10. Working with others in a multilingual environment and different cultural backgrounds.	0,00 0,00	0,00 23,02	0,00 34,62	76,92 47,31	23,08 0,00
	11. Facilitate the participation of all parties involved in the decision-making process during the development of my projects	0,00 0,00	0,00 15,38	11,54 38,46	53,85 46,15	34,62 0,00
Attitude and ethical professional.	12. Demonstrate an understanding of the importance of professional ethics and the consideration of all parties involved.	0,00 3,85	0,00 7,69	11,54 23,08	38,46 65,38	50,00 0,00
	13. Identify the potential challenges, risks and the consequences of how the engineering practice impacts on society and the environment	0,00 3,85	0,00 23,08	11,54 42,31	50,00 30,77	38,46 0,00
	14. Guide of ethical and responsible professional activity in the framework of organisations, administrations, companies or teams	0.00 3,85	0.00 23,08	15,38 30,77	53,85 42,31	30,70 0,00

3.3 How should be included the sustainability criteria within the engineering curriculum

The third question group was related to the curriculum and how must be included the sustainability criteria within the engineering curriculum (degree + master). There are defined three options: 1) embedded the sustainable concepts in the subjects, 2) show recent real cases, 3) develop projects.

The experts were asked to indicate 0,1,2, or 3 to each of the three levels assessing how you would have liked them to be incorporated into your studies and identify when they should be placed. (the higher the most suitable value).

Table 6. Importance of incorporating sustainability criteria

Description	0	1	2	3
Embedded the sustainable concepts in the subjects	0	46,15	42,31	11,54
Show recent real cases	0	7,69	23,08	69,23
Develop projects.	3,85	3,85	30,77	61,54

From the analysis of the result we can determine that a very appropriate way to introduce sustainability in the curriculum is though studying real cases, 69.23% gives the maximum score, although 61.54% also consider that they can be introduced with the development of projects. On the other hand, there is an 11.54% which would give the highest score to the introduction of concepts

Table 7 Proposal of distribution the sustainability criteria in the curriculum.

Description	1st-2nd	3º-4º	TFG	GRADE	GRADE +TFG	MASTER	TFM	MASTER +TFM	GRADE + MASTER
Embedded the sustainable concepts in the subjects	46,15	30,77	0	11,54	0	7,69	0	0	3,85
Show recent real cases,	0	42,31	3,85	0	11,54	23,08	0	7,69	11,54
Develop projects.	0	15,38	15,38	3,85	7,69	15,38	0	15,38	26,92

On the question of when we can realize that the introduction of concepts would be done in grade with preference in the 1st and 2nd year. The real case studies would be done preferably in the 3th and 4th . There isn't this consensus in considering when the development of projects should be introduced, the majority option is to be distributed in grade and master (26.92%). It should be noted that a (42.3%) believed that they can be done only in the grade and a (30.76%) prefer in the master.

4 How is applied in the Engineering curriculum.

4.1 Project P-15 Environmental Sustainability IQS of 2017-2020 Strategic Plan

The 4.1 Project P-15 Environmental Sustainability IQS of 2017-2020 Strategic Plan objectives are to consolidate the contribution and the presence of environmental sustainability in teaching, research and dissemination activities and to apply good practices to achieve a sustainable campus.

As sub-objectives related to the incorporation of sustainability in the training of the engineer it is proposed to promote cross-disciplinary sustainability content among various studies and engineering projects (TFG/TFM) to design a more sustainable Campus.

4.2 The ABET Program accreditation

Under the seven points for student outcomes listed in the Accreditation Board for Engineering and Technology criteria for accrediting engineering programs in the 2019-2020 accreditation cycle, two criteria strongly related to sustainability and sustainable development can be found. (ABET 2019) Unfortunately, the teaching of the sustainable development skills defined for outcome 2 can be particularly difficult for engineering faculty who must balance this against the need for increasing technical curriculum content. So, had been considered only ABET Outcome 4 in the distribution of the sustainability criteria in the curriculum. (Thürer et al. 2018)

Table 8. Graduates of Industrial Engineering MS program acquire the knowledge and develop the skills shown below:

OUTCOME	Description
1	They can identify, formulate and solve complex Industrial Engineering problems by applying principles of engineering, science, and mathematics.
2	They can apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3	They can communicate effectively with a range of audiences, both orally and in writing.
4	They recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of Industrial Engineering solutions in global, economic, environmental, and societal contexts.
5	They can function effectively on teams whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6	They can develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7	They understand the need for life-long learning, acquire and apply new knowledge as needed, using appropriate learning strategies.

Table 9. Distribution the sustainability criteria in the curriculum of the Bachelor and Master's degree program in Industrial Engineering at IQS School of engineering

ECTS -ABET OUTCOME	1st-2nd	3th-4th	TFG	GRADE	GRADE +TFG	MASTER	TFM	MASTER +TFM	GRADE + MASTER
ECTS	120	108	12	228	240	90	30	120	360
ECTS ABET- 4	16,5	37,5	12	54	66	31,5	30	60,5	104,5
ECTS ABET- 4 (%)	12,75%	34,72%	100%	23,68%	27,50%	35%	100%	50,41%	29,03%

Table 9 detailed the distribution of ECTS in the curriculum of the Bachelor and Master's degree and the number of ECTS of the subjects that had incorporate de ABET Outcome 4. The analysis showed that the percentages of credits enhanced by sustainable development do not follow the proposal obtained from the survey. Embedded the sustainable concepts in the subjects in the first two years was considered important and only 12.75% incorporated them. It is also low the percentage of credits related to sustainable development in the 3rd and 4th year.

Although the Finals Projects (TFG and TFM) consider the ABET 4 Outcome, the final percentage of sustainability related credits is only 29.03% of the total 360 credits.

5 Conclusions

The engineer should be able to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. (ABET, 2019) The 2030 agenda for sustainable development and the Sustainable

Development Goals (SDGs). (United Nations,2015) propose concrete actions that integrate multiple aspects with effective communicative strategies.

The survey has validated the opinion that the learning activities in the two first years would aim to understand the natural and social system present in our society, how humans have modified those systems and understand the role of technology based on models of successful experiences it is considered a priority for first contact right at the start of training to promote a particular way of thinking that incorporates a new aspect to the design of production process. (Kamp, L 2006)

As obtained from the survey, the competencies that allow technical projects to be carried out creatively, ethically and with critical thinking considering impacts, risks and social and the environment should be emphasized. These competences should be developed with active learning styles, using recent real cases and projects.

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