Education for Sustainable Development in Spanish Engineering Degrees. Case study

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Abstract

The purpose of this work is to present a methodology for analyzing the perception of engineering students about the sustainability learning they have achieved during their university studies. This study has been carried out in the context of the Spanish university system. Specifically, the opinion of 3364 students from nine engineering degrees of the Spanish university system taught at three universities is analyzed. In the framework of the EDINSOST project, a questionnaire of 34 questions related to four sustainability competencies has been designed and validated. To measure the learning declared by the students, composite indicators have been constructed and validated using factor analysis. The results show that students consider that they have achieved only two thirds of the sustainability competencies they should have on completion of their studies (66.3%). In the nine degrees, the worst results are obtained for the competency "application of ethical principles related to the values of sustainability", in which the fourth-year students declare having achieved, on average, only 53% of the expected learning outcomes. These results clearly show that engineering degrees should devote more time and effort to include Education for Sustainable Development in the curriculum. The methodology proposed in this work can be easily replicated in other contexts and in other countries.

Keywords
Sustainability learning, Sustainability competencies, Education for Sustainable Development, Sustainability in engineering degrees, Student's perceptions.

1.- Introduction

Global civilization has important challenges to face in order to secure the future of our planet (Ros et al., 2019). We live on a finite planet, but we do not take into account its limits in our activity as a species (Lade et al., 2020). Year after year, humans consume more than the planet is capable of regenerating. According to the latest data published by the research organization Global Footprint Network, in 2016 we were consuming the equivalent of 1.69 Earth planets (Global Footprint Network, 2019). In order to survive as a species, we need to consider sustainability in our activities.

The concept of sustainability was coined by Hans Carl von Carlowitz in the 18th century. Carlowitz was a manager of mining activity in the German city of Freiberg. The shortage of wood caused by the overexploitation of forests had a huge impact on the mining industry for silver extraction and on the metal industry of the time. Carlowitz proposed using the forest sustainably, felling only trees that could regenerate in a timely manner through planned reforestation (von Carlowitz, 1713).

Almost three centuries later, the Brundtland report defined sustainable development as “that which meets the needs of the present without compromising the needs of future generations”. While there are many definitions and controversies about the meaning of the concept of sustainable development and its implementation, a widely accepted framework to promote it is to achieve the sustainable development goals (SDGs) (Zamora-Polo and Sánchez-Martín, 2019). Although as recognized by Caiado et al. (2018), achieving the SDGs will not be an easy undertaking, important tasks and challenges must be addressed.

For the implementation of the SDGs to be effective, education is considered a key synergistic element (Lim et al., 2018; Giangrande et al. 2019; Hallinger and Chatpinyakoop, 2019; Aleixo et al., 2020). Indeed, Goal 4.7 of Sustainable Development Goal 4 addresses Education for Sustainable Development (ESD), and recognizes it as an essential factor for the achievement of sustainability (UN, 2015). In this paper, the terms sustainability and ESD will be used interchangeably as synonyms, although in some contexts some differences can be found between both concepts.

Promoting sustainable development at all educational levels is essential (Leicht et al., 2018), since we are educating future agents of change and transformation of society (Mulder et al., 2012) that will make the immediate future sustainable or not (Svanström et al., 2012). In this sense, the role of higher education is key to promoting the transition towards a more sustainable society (Stephens and Graham, 2010) and to deliver graduates to foster this transition (Stough et al., 2018). It is essential to create awareness in higher education about the social and moral responsibilities associated with professional practice (Sibbel, 2009). It is therefore essential that sustainability is integrated into HEI policies and strategies (Farinha et al., 2018), although as recognized by various researchers (Aleixo et al., 2018a), this does not always happen. Ávila et al. (2017) have analyzed the existing barriers to the introduction of ESD in 172 universities across all continents. They emphasize that a change of thinking is necessary, since ESD should not only be part of teaching, research and campus operations, but should also be embedded in the relationships with external partners. Fissi et al. (2021) highlight that including green issues (green building, waste management, etc.) in all the main dimensions of university activities is important to promote ESD.
Many researchers have studied methodologies to introduce sustainable development into the curriculum of universities (Mateus et al., 2020), and stress that promoting cross-disciplinary research is imperative in order to address the great challenges associated with ESD (Hensley, 2020). Some works have analyzed different models of introduction of ESD into higher education (Priyadarshini and Abhilash, 2020). Thurer et al. (2018) have analyzed, from 247 articles, the integration of sustainability in the curriculum of the engineering area. They conclude that the assessment of the results of the integration of sustainability in the curricula, in practice, is done quite superficially. Other authors have analyzed the key concepts to convey (Boni et al., 2016), and other research emphasizes the importance for academics to develop collaborative approaches and redesign their disciplines by taking into account the multicultural vision of sustainability (Filho et al., 2018). The introduction of SD should take into account the holistic and transdisciplinary vision of the concept (environmental, economic, social / cultural and institutional / educational / political) (Aleixo et al., 2016), although in their research conducted in Portuguese HEIs, Aleixo et al. (2018b) highlight that the implementation of SD is more advanced in some dimensions than in others. As some authors acknowledge, ESD practice must be extended to be more systemic and cross-disciplinary (Stevenson et al., 2017).

Other investigations use a bibliometric approach. This is the case of Tejedor et al. (2019), which have analyzed the keywords related to sustainability in engineering education in 171 papers. They conclude that, in recent years, the number of keywords related to institutional and university policy aspects to incorporate or apply sustainability in higher education has decreased, while the keywords related to the professional development of faculty members, and the implementation and use of learning strategies has increased.

Research has also been done about the competencies that should be included in the curriculum of universities for the introduction of sustainable development, and whether or not these competencies should be transversal, in addition to analyzing their degree of integration (Trencher et al., 2018; Lambrechts et al., 2013). Wiek et al. (2011) have identified five competencies related to sustainable development: systems-thinking, anticipatory, normative, and strategic and interpersonal competency. Other authors have investigated how they can be operationalized at different levels (Wiek et al., 2015). The UN adds other competencies to be considered: critical thinking, self-awareness and integrated problem-solving, (UNESCO, 2017). In addition to these competencies, other authors identify three other clusters of competencies: diverse modes of thinking, methodological plurality, and competencies for autonomy (Salovaara et al., 2019). It should also be noted the research by Lozano et al. (2017), which proposes a framework to relate competencies and pedagogical approaches in order to provide a more holistic and systemic approach to ESD.

Spanish universities have incorporated ESD in accordance with the guidelines of the document “Guidelines for the introduction of Sustainability in the Curriculum” approved by the Executive Committee of the CRUE (Conference of Rectors of Spanish Universities) Working Group on Environmental Quality and Development Sustainable in 2005, updated in 2011 (CRUE, 2012). These guidelines were approved before the UNESCO SDG (UN, 2015), although they are related to the competencies in ESD approved by the United Nations Economic Commission for Europe (UNECE, 2012).

The CRUE proposes four transversal competencies in sustainability that must be integrated into all university degrees in Spain (CRUE, 2012). Based on these competencies, the EDINSOST project (Segalàs and Sánchez-Carracedo, 2019) defines sustainability maps for different degrees. These sustainability maps contain the sustainability learning outcomes that a graduate must have declared on completion of
their studies. Sánchez-Carracedo et al. (2019) analyze the presence of ESD in the curricula of a set of engineering degrees in the Spanish university system using these maps.

The objective of this work is to analyze the level of sustainability competencies achieved by graduates of nine engineering degrees in Spain according to the Engineering sustainability map of the EDINSOST project.

2.- Material and methods

2.1.- Objectives and Research questions

To achieve the main objective, a comparative approach is adopted. Specifically, this paper explores the level of uniformity of improvements in sustainability competencies between domain levels, universities and degrees. Likewise, the paper has two goals: to investigate the existence of patterns beyond the general trend, and to analyze if there is evidence that confirms the existence of university policies for the acquisition of competencies related to the SDGs.

This study is based on the following research questions:

- Q1: How much do engineering students in the Spanish university system improve their sustainability competencies during their studies at the university?
- Q2: Is the improvement homogeneous in all the domain levels of the analyzed competencies??
- Q3: Is the improvement homogeneous in all the degrees analyzed?
- Q4: Is the improvement homogeneous in all the universities analyzed?

2.2.- Instruments

To answer the four research questions, the EDINSOST project engineering sustainability map (Sánchez-Carracedo et al., 2019, 2018b), which can be found in the Supplementary Material, is used as a starting point. The sustainability map is a competencies map (Sánchez-Carracedo et al., 2018a) that contains the sustainability competencies defined by the CRUE (2012). Each competency is defined by one or more Competency Units (CU), and for each CU a set of learning outcomes is defined. Learning outcomes are classified using the simplified Miller pyramid as taxonomy (Miller, 1990; Sánchez-Carracedo et al., 2019, 2018b), which has three domain levels: Know, Know how and Demonstrate + Do. Table 1 shows the competencies and CUs of the engineering sustainability map.

Table 1: Competencies and CUs of the Education Sustainability Map (see Sánchez-Carracedo et al., 2019 for a complete description).

<table>
<thead>
<tr>
<th>C1. Critical contextualization of knowledge</th>
<th>1.1 Historical perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2 Creativity and innovation</td>
</tr>
<tr>
<td>C2. Sustainable use of resources</td>
<td>2.1 Considers sustainability as an engineer</td>
</tr>
</tbody>
</table>
Based on the learning outcomes of the Engineering Sustainability Map, the EDINSOST project has defined and validated a questionnaire of 34 questions. The questionnaire can be found in the supplementary material.

### 2.3.- Methodology

The questions in the questionnaire are statements that are answered according to a 4-point Likert scale: "Strongly disagree", "Disagree", "Agree" and "Strongly Agree". To perform the statistical treatment of the responses, a numerical value was assigned to each of the responses: value 0 for "Strongly disagree", value 1 for "Disagree", value 2 for "Agree" and value 3 for "Strongly agree". The Engineering Sustainability Map has 24 cells, and each cell contains one or more learning outcomes. Since the questionnaire contains 34 questions, some of the questions refer to the same cell on the map. The supplementary material presents a table with the relationship between the questions and the cells of the Sustainability Map.

To validate the questionnaire, a group of 15 experts and a control group consisting of 20 final year students were formed. Both the group of experts and the control group assessed the relevance and clarity of each question, also indicating whether they considered that any question should be eliminated or added. The description of the validation process can be found in Sánchez-Carracedo et al. (2018c).

The questionnaire was developed using the Google Forms tool. The data collection was carried out during the second semester of 2018. First- and fourth-year students from various degrees taught at various universities answered the form. Sample data is presented in Section 2.4. The data analysis was performed with aggregated data, since the study is not longitudinal nor is the number of responses uniform in all degrees and universities.

To analyze the information collected in the questionnaires, two composite indicators were created. These tools are useful for maximizing information and reducing complexity in a valid, reliable and precise way (de Vaus, 2002). A composite indicator is a statistical technique that transforms individual variables, in this case Likert items, to generate an aggregate measure that facilitates the transmission of information about
the phenomenon studied. Variables have been defined to represent the different aspects to be analyzed (Competencies, CUs and domain levels), provided that these aspects are made up of more than one Likert item. The relevance of generating methodologically adequate indicators lies in avoiding simplistic aggregations and providing transparency in their construction that benefits the indicators, especially in terms of credibility and replicability (Rosen, 1991 in Nardo et al., 2008).

The construction of the first composite indicator consists of three stages: First, the preparation of the information. The median was imputed to the missing values, and the variables were standardized, since a significant proportion of items had skewed distributions. Furthermore, a one-dimensionality and reliability analysis was performed to confirm that all the questions referring to the same competency, CU or domain level formed a single underlying concept (de Vaus, 2002). Using PCA, it was possible to evaluate the likelihood of reducing the number of analysis dimensions while losing the minimum amount of information. Although PCA is regularly practiced for ratio scale variables, recent applications to ordinal scale variables exist that justify its application in this work (Vermunt and Magidson 2005 in Nardo et al., 2008). In the PCA, Kaiser Criterion (1960) was applied by selecting only those components with eigenvalues greater than 1. It was also ensured that these components explain a minimum of 10% of the variance, and that the sum of all the selected components explains a minimum 60% of the cumulated explained variance. All PCAs confirmed the ability to summarize in the foreseen dimension (Competency, CU, domain level).

Next, once the appropriate treatment for Likert items has been defined, the composite indicators are constructed. The factorial scores of the PCA components are then obtained, provided that the KMO test and the Bartlett sphericity test confirm the quality of the results (de Vaus, 2002). Finally, to provide semantic meaning and facilitate the interpretation of the data (de Vaus, 2002), the composite indicators, which are normalized variables with mean 0 and standard deviation 1, are transformed to the original unit of measurement 0-3. This indicator is called absolute learning in Section 3 and Equation 1 is used to calculate it:

\[
\text{CI} = \frac{CI_{\text{min}} - CI_{\text{max}}}{CI_{\text{max}} - CI_{\text{min}}} \times 3;
\]

CI being the composite indicator.

A second composite indicator was constructed from the first to measure the increase in student learning in sustainability competencies. This indicator is the ratio resulting from the relationship between the indicator of acquisition of sustainability competencies of fourth-year students and first-year students, based on the learning they could achieve about the learning declared by first-year students\(^1\). Since the data has been obtained through a cross-sectional study, and not through a data study panel, the learning percentage indicator will be a university/degree-aggregated indicator. This indicator is called “relative learning” in Section 3, and the formula to calculate it is presented in Equation 2.

\[
\text{Equation 2: } \frac{AL_{\text{4}} - AL_{\text{1}}}{3 - AL_{\text{1}}};
\]

\(^1\) First-year students declare having a certain level of sustainability when they enter university, greater than 0. If the level they declare to have is \(X\), measured between 0 and 3, the percentage of improvement they have is \(\frac{(3 / x) - 1}{3} \times 100\).
AL_ being the 4th course university/degree-aggregated learning, and AL_ the 1st course university/degree-aggregated learning.

2.4.- Sample

This work analyzes four engineering degrees from three universities: The Universidad Politécnica de Catalunya - BarcelonaTech (UPC), the Universidad Politécnica de Madrid (UPM) and the University of Seville (US). The degrees analyzed are the Bachelor Degree in Informatics Engineering (BDIE), the Bachelor Degree in Mechanics Engineering (BDME), Bachelor Degree in Chemical Engineering (BDCHE), and the Bachelor Degree in Industrial Technologies Engineering (BDITE). Not all degrees are taught at all universities, so the final number of degrees analyzed is nine instead of twelve. Table 2 presents the number of first- and fourth-year students who have answered the questionnaire, classified by university and degree. In Table 3, the data is broken down to identify how many students from each degree and course have answered the questionnaire at each university.

Table 2: Number of first- and fourth-year students classified by university and degree.

<table>
<thead>
<tr>
<th>University</th>
<th>Bachelor Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UPC</td>
</tr>
<tr>
<td>1º</td>
<td>278</td>
</tr>
<tr>
<td>4º</td>
<td>238</td>
</tr>
<tr>
<td>Overall</td>
<td>516</td>
</tr>
</tbody>
</table>

Table 3. Number of students from each degree and course who have answered the questionnaire at each university.

<table>
<thead>
<tr>
<th>University</th>
<th>Bachelor Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BDIE</td>
</tr>
<tr>
<td>1º</td>
<td>219</td>
</tr>
<tr>
<td>4º</td>
<td>227</td>
</tr>
<tr>
<td>Overall</td>
<td>446</td>
</tr>
</tbody>
</table>
3.- Results and discussion

To answer the four research questions, this section shows several figures that contain two grouped bar graphs labeled as (a) and (b). The figures labeled as (a) represent the learning declared by fourth-year students and the increase in learning declared by these students with respect to that declared by first-year students, both calculated by using Equation 1. The figure range varies from 0 to 3, according to the numerical transformation described in the methodology. The figures labeled (b) represent, in percentage, the relative learning declared by fourth-grade students, calculated according Equation 2; that is, the percentage of learning that these students achieve with respect to what they could have declared. The different figures shown in this section represent the students' declared learning in terms of competencies, CUs and domain levels.

3.1.- Research question 1

Figures 1 and 2 allow us to answer the first research question: How much do engineering students in the Spanish university system improve their sustainability competencies during their studies at the university?

3.1.1. Analysis by competencies

Figure 1 shows the learning declared by the students in each competency and on average. The figure shows that the learning declared in the four competencies is different. On average, first-year students report learning close to 50% (1.49 out of 3) when they enter university, and fourth-year students 66% (1.99 out of 3). This implies an average relative learning of 33%, as observed in Figure 1 (b).
Figure 1. Learning declared by students in each competency and on average.

Clearly, C4 (ethics) is the competency in which students declare less learning both in absolute terms (1.59 out of 3) and in relative terms (24%). This result is worrying. The formation of a civic ethic, both in personal and ethical conduct, must be reinforced in engineering. Strengthening ethical values such as global perception is essential, as it reinforces other values such as solidarity and responsibility (Morin, 2001), promoting human development and the common good. In addition, we consider that the teaching of a civic ethic must be transversal and, therefore, permeable in different courses and subjects, from the most basic of the first course to the most specialized of the final courses.
Figure 1 also shows that C3-Participation in community processes is the competency with the highest relative learning (39%), followed by C2-Sustainable use of resources and C1-Critical contextualization of knowledge (35% and 32%, respectively). However, there are hardly any relevant differences in the declared absolute learning in these three competencies (≈ 2 out of 3). The absolute competency learning declared by the fourth-year students follows the gradation: C4 < C2 < C1 < C3.

3.1.2. Analysis by Competency units

Figure 2 shows the learning declared by the students in each CU. Since C3 and C4 have only one CU, the data shown in this figure is identical to that shown in Figure 1 for these two competencies and does not need to be analyzed. However, C1 and C2 have more than one CU.

![Graphs showing learning in each competency unit](a)

![Graphs showing learning percentage in each competency unit](b)

Figure 2. Learning declared by students in each competency unit.

The comparative analysis of Figures 1 and 2 for these UC shows that:
The absolute learning of the CUs in C1 is similar, but differences are observed in relative learning. Relative learning for CU1.1 - historical perspective is 34%, compared to 29% for CU1.2 - creativity and innovation. Learning, both absolute and relative, follows the gradation: CU1.1> CU1.2.

The absolute and relative learning of C2 is different in the four CUs. CU2.2 - environmental impact is the CU where students declare less learning, both in absolute terms (1.91 out of 3) and in relative terms (29%).

CU2.4 - management of engineering projects is the CU of the C2 with the highest relative learning (44%), despite the fact that the CU2.3 - social impact presents slightly higher absolute learning.

The results clearly show that engineering curricula focus on working on the economic aspects of projects, while neglecting environmental aspects. Teachers often talk about development and sustainable development, blurring the line between development and sustainability (Mayer, 1998). Thus, a classic prejudice among engineering students is, for example, that "the best technology will win the market" (Mulder et al., 2012). However, it is also important for an engineer to learn about the use and conservation of resources (CU2.2). In other words, learning about the implementation of clean and economically viable production processes that contribute to development but, at the same time, mitigate the impact of the human footprint.

On the other hand, engineers must understand and be aware of the complexities of the environment in which they carry out their work. They must be able to recognize the interrelation, circumstances, risks, coincidences, dangers of all phenomena and, consequently, accept to live with uncertainty (Mayer, 1998). Living with the unpredictable favors critical thinking and responsible and creative decision-making in the face of possible alternative scenarios. This leads us to the opinion that a greater learning in CU1.1 would enable better results to be obtained in the learning of CU1.2.

In engineering studies, training students in creativity and innovation is essential, since it involves the imagination and promotes the development of original ideas (Hensley, 2020).

3.2.- Research question 2

To answer the second research question, “Is the improvement homogeneous in all the domain levels of the analyzed competencies?” Figure 3 is presented.
Figure 3 shows the learning declared by the students at each domain level (L1-know, L2-know how and L3-demonstrate + do) of each competency and the mean for each level. Different learning is observed in the three domain levels:

- Students report greater absolute learning at the highest levels of the taxonomy (L3) except for C2-sustainable use of resources. In C2, learning is higher at the intermediate level of taxonomy (L2-know how). C3 is the most balanced competency, and students achieve very similar learning at all three domain levels.
- Regarding relative learning, the L1 and L3 levels of C3-participation in participatory processes stand out. C4-ethics does not exceed 25% in any of the
three levels, and the same is true for level L1 of C1-contextualization of knowledge.

- Although the four competencies behave differently when their domain levels are considered, on average both absolute and relative learning are greater at the highest levels of the taxonomy in increasing order (L1 <L2 <L3). In particular, at levels L2 and L3, first-year students report absolute learning of close to 50% (1.47 and 1.49 out of 3, respectively), and fourth-year students around 66% (1.96 and 2.00 out of 3 respectively). This implies an average relative learning that ranges between 31% (L1) and 34% (L3). In other words, fourth-year students declare that they have learned in the three domain levels approximately a third of what they could have learned.

These results can be explained by the development of more application-oriented tasks in engineering education (Tejedor et al., 2018). The concern to find solutions to problems is inherited from a learning that has often been compartmentalized, divided up and atomized, in a school that focused its attention on the application of heuristics (L3) rather than on deepening knowledge (L1) and understanding (L2) of problems. However, it is at the levels of knowledge (L1) and understanding (L2) where it is necessary to adopt a more critical and reflective approach about the reasons that exist (or not) to make certain decisions when addressing a problem or task. The continuous taking of sustainable decisions and the application of such decisions (L3) requires prior knowledge and understanding (L1, L2) of the problems. This makes us reflect on the need not only to increase learning in the different domain levels (L1, L2, L3), but also to seek its balance in each of the four competencies analyzed.

3.3.- Research question 3

Figures 4, 5 and 6 allow us to answer the third research question: Is the improvement homogeneous in all the degrees analyzed?

3.3.1. Analysis by competencies and degrees.

Figure 4 shows the learning declared by students in each competency organized by degrees. The comparison of Figures 1 and 4 indicates that the BDIE is the only degree in which the learning of fourth-year students behaves as the mean: C4 <C2 <C1 <C3. In the BDME, the relative learning declared for C4-ethics stands out (44%) compared to the average relative value for this competency (24%, see Figure 1 (b)). As already happens in the mean, C4 is the competency that obtains the worst learning results in absolute learning in every degree.
The students of the four degrees analyzed declare a different absolute learning pattern in the four competencies, but the declared values are similar for C1, C2 and C3 (≈2 over 3). However, in relative learning there is a lot of variability. BDME students report good results in all four competitions, BDIE students excel in C3, and BDITE students in C2 and C3 (in all cases, learning is above 39%).

3.3.2. Analysis by competency units and degrees.

Figure 5 shows the declared learning by students in each CU organized by degrees. Since C3 and C4 only have one CU, the data shown in this figure is identical to that shown in Figure 4 and does not need to be analyzed.
Relative learning in CUs (Figure 5 (b)) has a lot of variability in the four degrees. In general, BDME and BDITE students report higher relative learning compared to BDIE and BDCHE students. However, the absolute learning declared in the four degrees is similar, as already observed in Figure 4.

A more exhaustive analysis of Figures 4 and 5 highlights the following aspects:
In general, there are differences between the relative learning of CU1.1-historical perspective and CU1.2-creativity and innovation, except for the BDIE. The absolute learning declared by the students for CU1.1, however, is greater than that declared for CU1.2, except for the BDIE, in which the opposite occurs.

The pattern for absolute and relative learning for C2's CUs is different in all four degrees. CU2.2-considers environmental impact, is the CU with the least relative learning in the BDIE and BDME (10% and 43%, respectively). CU2.4-management of engineering projects, is the CU with the highest relative learning achieved in three of the four degrees studied (BDIE, BDCHE and BDITE). In the BDME, the four CUs reach very similar values.

These results are consistent with the analysis made for Figure 2. However, depending on the degree analyzed, some of these results differ from those presented in Figure 2. This is the case of the BDCHE and BDITE students, who state that they possess less learning in knowledge of sustainable engineering projects considering, holistically, environmental, economic and social aspects (28% and 39%, respectively). On the other hand, BDME students declare more learning (48%) in aspects related to accessibility, ergonomics, safety and, ultimately, how to contribute to improving the common good of society.

3.3.3. Analysis by competencies and degrees broken down according to university.

Figure 6 shows the learning declared by the students in each competency for each degree at each university. The analysis of the data presented in this figure indicates that students of the same degree perceive a different relative learning in the four competencies according to the university where they study. In BDIE and BDITE, the low relative learning declared in the US with respect to that declared in the other universities stands out. The BDCHE is the degree which presents more differences between universities: at UPM, relative learning is higher in C2 (39%) and C3 (36%), while in the US it is higher in C1 (31%) and C4 (25%).
In absolute learning, however, the differences between the four competencies are not so evident, and the BDME is the degree in which students declare more uniform learning in the two universities where it is taught.

Clearly, the same degree develops sustainability competencies differently depending on the university. We can therefore conclude that these competencies are not considered within the core competencies of the degree, and that each university develops them according to local criteria. Thus, in response to the research question, learning in sustainability of the four competencies is different depending on the degree and, for the same degree, it is different depending on the university in which it is taught. This is probably due to the fact that, unlike in other countries, in Spain there is no clear state or regional strategy that supports the application and development of ESD policies in higher education.

3.4.- Research question 4:

Figures 7, 8 and 9 enable us to answer the fourth research question: Is the improvement homogeneous in all the universities analyzed?

3.4.1. Analysis according to competencies and universities.

Figure 7 shows the learning declared by the students in each competency according to universities. In the three universities studied, the competency in which the students declare the least absolute and relative learning is C4-ethics, while the greatest absolute and relative learning is in C3-community processes. Both absolute and relative learning present similar patterns in the three universities. The absolute learning declared by the students for C2-sustainable use of resources is slightly lower than that declared for C1 and C3, while for C4 it is clearly lower than that of the other three competencies, obtaining its highest value in the UPC (35%). Regarding relative learning, the lowest value is declared for C4, while for the other competencies C3> C2> C1. The University of Seville stands out in a negative way, since it does not exceed 28% of relative learning in any of the four competencies.
Figure 7. Learning declared by students in each competency, according to universities.

3.4.2. Analysis according to competency units and universities.

Figure 8 shows the declared learning by students in each CU for each university. Since C3 and C4 only have one CU, the data shown in this figure is identical to that shown in Figure 7 and does not need to be compared.
Regarding C1 - contextualization of knowledge, the two CUs present very similar values in absolute learning in the three universities. However, differences are observed in relative learning. The UPC and the US achieve better results in CU1.1 - historical perspective, while the UPM achieves slightly better results in CU1.2 - creativity and innovation.

Regarding C2 - sustainable use of resources, at UPC students report considerably less learning in CU2.2 - consider environmental impact, compared to other CUs. In the UPM students declare that they learn less in the CU2.2 - consider social impact, and in the US the least learning is declared for the CU2.1 - consider sustainability as an engineer and CU2.2 - consider environmental impact.

Fourth-year students at the UPC and UPM report more learning about how to maximize the positive impact of their professional activities on society than US students. On the other hand, students from the three universities declare more relative learning in aspects related to the management and economic viability of an engineering project, their planning techniques and process optimization. This allows us to affirm that the analyzed universities focus their learning related to resource management on project management, without taking into account their sustainability.

3.4.3. Analysis by competencies and universities broken down by degrees.

Figure 9 shows the learning declared by the students in each competency for each university organized by degree. Relative learning is different in the four competencies between students from the same university according to the degree they study. This seems to suggest that, within the same university, there is no common policy to develop ESD in all degrees. It seems that each degree develops its own policy, either because it is defined by its management teams or because that policy does not exist and depends on what teachers do in their subjects.
Figure 9. Declared learning by students in each competency for each university and in each degree.

Regarding absolute learning, the UPC obtains similar values in its two degrees, except in C4-Ethics of the BDIE. The behavior of the BDIE is consistent with the rest of the analysis carried out in this paper for the rest of the degrees. The BDME, on the other hand, presents a learning in C4 similar to that of the rest of the competencies, being the only degree of the nine studied in which this happens. In addition, it presents the highest learning values both absolute and relative for C4 in comparison with the rest of the degrees. This is undoubtedly due to the fact that those responsible for the degree, or the professors in charge of working at ESD, are especially aware of ethical issues and have incorporated this competency into the curriculum.

The three degrees at UPM also behave differently in both absolute and relative learning, so we assume that there is no university policy on ESD either. In the BDIE the learning of C3-Community processes stands out, probably due to the knowledge that computer engineers have of collaborative work tools (since the same happens in computer engineers from other universities). BDITE seems to be the degree that achieves the highest relative learning in all competencies. This may be due to the fact that the first-year students of this degree are those who declare a lower level in the four competencies when they begin their studies, so they have a greater margin for improvement. This fact is striking, since an expected result was that first-year students from all degrees and universities present similar results. The fact that the average access marks are different in the different degrees probably has an influence in the fact that the first-year students declare a different learning depending on the degree in which they have enrolled. The number of students who have answered the survey at the BDITE of UPM is very high, so this does not seem to be a factor that could account for the difference.

Finally, at the US, the BDIE is the degree that presents a worse relative learning, despite the fact that in absolute learning there are no significant differences with the rest of degrees, except perhaps with regard to C4-Ethics, in which there is hardly any improvement in learning. The other three degrees present very similar values regarding absolute learning. In relative learning, however, the results reported by BDME students stand out, as was the case at the UPC. Perhaps the very nature of Mechanical Engineering studies encourages students to develop the four sustainability competencies. However, while this could be reasonable for C1, C2 and C3, it is curious to observe that it also occurs in C4-Ethics. There does not seem to be any compelling reason for mechanical engineering students to declare themselves more competent in ethical issues than the other engineering students at their university, but this is the case in the two mechanical engineering degrees we have studied.

These results highlight aspects, in part, expected. Unlike what happens in other neighboring countries such as Sweden or Wales, in Spain no centralized system exists to implement ESD in HEI. While universities enjoy some institutional autonomy (Farinha et al., 2018), as in Portugal, in the Spanish context CRUE (2012) proposes a series of “recommendations” to integrate sustainability into university curricula. Consequently, this work can be considered as part of a local action that seeks to “measure” the degree of implementation of a more global “recommended agenda”, such as the integration of the four CRUE sustainability competencies throughout the Spanish university system. From this perspective, the case study presented could successfully connect a bottom-up approach with professional bodies in a kind of mixed implementation.

3.4.- Limitations of this work
This work presents some limitations that must be considered when interpreting the results. First, only 4 degrees taught at 3 universities have been studied. Second, the student sample is large, but a larger sample, including more degrees and more universities, is needed to draw definitive conclusions beyond a case study. Third, this study is not longitudinal, but of the repeated cross-sectional type, in which the samples from each course do not include the same subjects nor are they collected at different times (Bryman, 2016). In other words, the first- and fourth-year students who have answered the questions are not the same, nor have three academic years elapsed between the two surveys, which were conducted in the same semester. The observed improvement should therefore be interpreted as an overall improvement, although we do not know if this improvement occurs on the surveyed students. Even if it were a longitudinal study, we could not rule out that other factors may have influenced learning. What we are able to say that the results presented reflect the increase in learning on average, but not the average increase in learning, which would require the surveys to have been answered by the same students when they took the first and fourth grades. Fourth, the students were not randomly selected, but responded voluntarily to the survey. Finally, the survey measures the perception of students regarding their own sustainability competencies, not their actual knowledge.

4.- Conclusions and future work

This work analyzes the perception that the students of nine engineering degrees taught in three universities have about their sustainability competencies. This perception is measured using two composite indicators: absolute learning and relative learning. Absolute learning measures students' perception of learning at a given stage of their studies. Relative learning measures the percentage of learning that students claim to have achieved at the end of their studies compared to what they should have at a given moment. The study presented in this paper compares the first- and fourth-grade students' perception of four sustainability competencies:

- C1. Critical contextualization of knowledge by establishing interrelations with social, economic, environmental, local, and/or global problems.
- C2. Sustainable use of resources and prevention of negative impacts on the natural and social environment.
- C3. Participation in community processes that promote sustainability
- C4. Application of ethical principles related to the values of sustainability in personal and professional behaviour.

The most important conclusion of this work is that, of the four sustainability competencies analyzed, the “application of ethical principles related to the values of sustainability” is the least developed in the nine degrees studied, according to the students' perception. However, strengthening ethical values such as global perception is essential, as it reinforces other values such as solidarity and responsibility (Morin, 2001), promoting human development and the common good.

On average, students stated that they already know half of what they should know when they enter university in the four competencies, while in the fourth year they achieve only two thirds of the learning they should have achieved. Nevertheless, mechanical engineering students seem to feel more prepared in this competency than students from other degrees.

In addition to the poor results obtained in terms of ethical principles, it is surprising that students state that they feel less competent in the “sustainable use of resources” (a
competency directly related to engineering studies) than in the “critical contextualization of knowledge” or in "participation in community processes". It is important for an engineer to learn about the use and conservation of resources; in other words, learning about the implementation of clean and economically viable production processes that contribute to development but, at the same time, mitigate the impact of the human footprint.

Engineers must be aware of the complexities of the environment in which they carry out their work. They must be able to recognize the interrelation, circumstances, risks, coincidences and dangers of all phenomena (Mayer, 1998). However, the results presented in this paper show that engineering curricula seem to focus on working on the economic aspects of projects, while neglecting environmental aspects.

The continuous taking of sustainable decisions and the application of such decisions (Level L3 of the learning taxonomy) requires prior knowledge and understanding (Levels L1, L2) of the problems. However, the results presented in this paper show that students report greater absolute learning at the highest levels of the taxonomy (L3) except for “sustainable use of resources”. Although the four competencies behave differently when their domain levels are considered, on average both absolute and relative learning are greater at the highest levels of the taxonomy. These results can be explained by the development of more application-oriented tasks in engineering education (Tejedor et al., 2018). However, engineering degrees should not neglect the development of the lower levels of the taxonomy, since it is crucial that students have a solid theoretical foundation of the methodologies they apply.

No pattern between degrees or universities is identified in this study. The same degree develops sustainability competencies differently depending on the university. Relative learning is different in the four competencies between students from the same university according to the degree they study. In other words, there are no degrees or universities in which students declare to have clearly achieved a higher level of sustainability competencies on completion of their studies. The results suggest that the analyzed universities have no policy for the inclusion of ESD in their degrees. This policy could exist independently in each degree, or it may not exist at all. This situation is coherent in the Spanish context, where there is no centralized system to implement ESD, although the universities do enjoy a certain institutional autonomy. Thus, the results may depend directly on the motivation of the professors of each degree to include ESD in their subjects.

It is possible that the students’ access grade influences the results of this work. Perhaps the students of degrees that have a lower access grade declare a lower level of sustainability competencies at the beginning of their studies, and therefore have a greater capacity for improvement. However, the students of the US, in general, declare to have a higher level of sustainability competencies when they begin their university studies than students of other universities. This fact is probably due to the Kruger-Dunnin effect (Kruger and Dunnin, 1999): “an individual with fewer competencies and less knowledge has an illusory feeling of superiority, considering himself / herself to be more intelligent than another better prepared individual”. Analyzing whether or not that this is a factor of influence forms part of the authors’ future work.

Taking into account the results presented in this work, engineering degrees should improve the way they develop ESD in order to enable students to achieve the third part, which they state they are not currently achieving. It is curious that some published studies indicate that the study guides for engineering subjects declare that professional ethics is the competency that is most developed among the four competencies of the CRUE (Sánchez-Carracedo et al., 2019). This contradiction implies that it is necessary to carry out future work to compare the results of this work with the results that would be
expected from the subject learning guides. This analysis could provide a valid methodology to help identify weaknesses in the teaching and learning processes of the subjects in the degrees in order to correct them, and that such processes can be effectively implemented in regard to ESD, thereby favouring full coherence between theory and practice.

If the HEI pursue the training of critical and reflective professionals who not only possess the appropriate knowledge in their discipline, but also the confidence that their actions as engineers can contribute to the construction of more sustainable societies through the exercise of their profession, it is necessary to analyze the perception that engineering students have regarding their degree of acquisition of sustainability competencies, as well as to identify difficulties and interferences in their development.

The tasks identified in the last two paragraphs are part of the future work of the authors within the EDINSOST2-ODS project. The results of the work presented in this paper belong to the EDINSOST project, which was an analysis project. EDINSOST2-ODS is an intervention project that focuses on integrating ODS in a set of seven degrees from eight universities. The degrees sample includes three levels of incidence. First, a degree related to one of the three dimensions of sustainability (environmental, social and economic) will be studied: the Degree in Business Administration and Management. Second, because of its long-term multiplier effect, two undergraduate degrees in the sciences of education (Pedagogy and Primary Education) will be analysed, since their graduates are the future teachers of the new generations of citizens. Finally, covering the short-term effect, work will be done on technological degrees (informatics engineering, telecommunications engineering, industrial technology engineering and design engineering), for its great impact on the challenges of society.

The EDINSOST2-ODS project is aligned with European strategy Horizon 2020. The transdisciplinarity in the approach to address the challenge on which the project is based arises from the need to form interdisciplinary teams, capable of providing value in what is the implementation of actions in educational institutions that seek programs with greater implications of social responsibility, the development of values oriented to commitment and social change.

The results of EDINSOST2-ODS will allow:

- Improve ESD in the degrees studied, increasing student learning and knowledge of teachers. As previously commented, EDINSOST aimed to analyse the situation in ESD in Spain. EDINSOST2-ODS will implement improvements in some degree curricula and will evaluate the cost of implementing these improvements in other degrees after the project is finished.
- Train some teachers of the degrees studied so that they incorporate the SDGs in their teaching.
- Measure how students' learning evolves throughout the 4 years of the bachelor degrees and the project to verify the effectiveness of the work developed in the project.

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