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Education for Sustainable Development in Spanish Higher Education: an assessment of sustainability competencies in engineering and education degrees

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Abstract

Purpose

This paper presents a methodology for analysing the extent to which students of a university degree perceive that they have received a good Education for Sustainable Development (ESD). The methodology enables us to quantify this perception, which in turn allows us to determine (1) to what extent the objectives related to ESD are achieved in the degree, and (2) to compare the learning in ESD perceived by students of different degrees. The methodology is applied to nine engineering degrees and nine education degrees in the Spanish university system.

Design/methodology/approach

ESD is analysed from the students' learning perception. This perception is measured by comparing the responses of first- and fourth-year students to a questionnaire about their sustainability competencies. Two indicators have been designed to analyse the results. The first indicator, learning increase, measures the declared learning difference between fourth- and first-year students. The second indicator, learning percentage, measures the amount of learning as reported by fourth-year students compared to how much they could have learned.

Findings

The results show that the average learning percentage perceived by students is higher in engineering degrees (33%) than in education degrees (27%), despite the fact that the average learning increase declared by students at the end of their studies in both areas of knowledge is similar (66%). Engineering students report having achieved higher learning than education students in all sustainability competencies, with the exception of ethics.

Originality

This paper analyses ESD from the student's perspective. Furthermore, to the knowledge of the authors, this is the first work that compares the perception of ESD between engineering and education students. This comparison allows us to determine the different approaches that university professors take to ESD according to the discipline they teach.

Keywords

Higher education for sustainable development, education for sustainability, sustainability learning, sustainability competencies, sustainability in education degrees, sustainability in engineering degrees.

1. Introduction

Humanity is experiencing continuous population growth that requires continuous growth in the consumption of resources, which has a significant impact on the planet. Progress towards a more sustainable society constitutes a great challenge, since while the needs of human development must be met, they must also be satisfied by protecting the earth's life support systems (Cash *et al.*, 2003).

In recent decades, the UN has developed strategies and published agendas in the move towards sustainability, such as the Brundtland report, the Rio 92 Declaration on Environment and Development, and the current Agenda 2030, which promotes the Sustainable Development Goals (SDG). Most of these agendas and declarations recognise that education plays an important role in achieving a more sustainable future.

As open spaces for knowledge and reflection, Higher Education Institutions (HEIs) must adopt a leadership role in the development of strategies to solve the multiple challenges that humanity faces (Leal *et al.*, 2020). They must be able to train active and responsible graduates capable of facing future challenges (Stephens and Graham, 2010). In addition, they must know how to take advantage of the strategic opportunities in their environment to promote development at a social and economic level, which includes the design of participation strategies that involve external stakeholders (de la Torre *et al.*, 2019).

It is essential that sustainability is integrated into the HEIs' policies and strategies (Farinha *et al.*, 2018). Aleixo *et al.* (2018) show that, during the UN Decade of Education for Sustainable Development (UNESCO, 2014), the commitment of HEIs to sustainability increased. Since then, numerous studies and initiatives have been undertaken to identify barriers, challenges, opportunities and best practices that enable HEIs to step up their commitment to sustainability.

Some research analyses the difficulties and challenges faced by HEIs when planning how to incorporate Sustainable Development into higher education (Leal Filho *et al.*, 2018; Leicht *et al.*, 2018). Some authors advocate improved management and sustainability performance reporting (Adams, 2013; Lozano, 2011). Others analyse campus initiatives that reduce the environmental impact of HEIs (Amara *et al.*, 2020).

Much research is focused on how to implement sustainability effectively in the university curriculum, a task in which the involvement of the teaching staff is essential. Research conducted by Shepard and Furnari (2012) at a New Zealand university revealed that only a third of the 43 study participants advocated Education for Sustainable Development (ESD), which is a significant barrier to overcome. It is important to develop the educators' capacities so that they can implement transformative pedagogies when they do ESD (Qablan, 2018).

Some authors analyse the integration of the SDGs in the courses taught by the HEIs. Aleixo *et al.* (2020) have analysed 33 Portuguese public HEIs at the level of undergraduate and master's degrees, concluding that the majority of courses that work on and integrate the SDGs are in the areas of social sciences and humanities as well as environmental sciences. Other authors analyse different initiatives to integrate sustainability. Sales de Aguiar and Paterson (2018) analyse proposals carried out through projects that use a dialogical approach in a Scottish university, concluding that they provide a good opportunity for the creation of knowledge in a democratic and emancipatory way.

Other researchers analyse which competencies should be addressed to promote ESD. Wieck *et al.* (2011) identified five competencies: systems-thinking, anticipatory, normative, strategic and interpersonal competency, while Rieckmann (2012) identified twelve key competencies.

The most important are those for systemic thinking, anticipatory thinking and critical thinking. Other papers analyse how sustainability competencies can be implemented at different levels: novice, intermediate and advanced (Wiek *et al.*, 2015). Finally, some authors analyse the implications of formal and non-formal learning environments for the development of key competencies, paying special attention to interdisciplinarity and students' self-responsibility (Barth *et al.*, 2007).

The Spanish Higher Education System has recently received much attention in the literature. In this sense, Gonçalves Quelhas *et al.* (2019) identify eight sustainability competencies necessary for engineering professionals. Other studies prescribe the cross-curricular approach, participatory methodologies, and the development of values and competencies as the best ways to promote the implementation of ESD in higher education (Poza-Vilches, 2019). On the other hand, some empirical studies try to examine the presence of sustainability competencies in the Spanish university system (Aginako *et al.*, 2021; Sánchez-Carracedo *et al.*, 2021a).

The Spanish HEIs have followed the CRUE guidelines for incorporating ESD (CRUE, 2012). CRUE, the Conference of Rectors of Spanish Universities, is an organization made up of 75 public and private universities that plays a key role in the development of higher education in Spain. These guidelines were approved before the publication of the SDGs, although they integrate the competencies in ESD approved by UNECE (2012). The CRUE proposes to implement ESD in the curriculum of all university degrees in Spain using four transversal 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.

Based on these four competencies, the (Sánchez-Carracedo *et al.*, 2021a) defines sustainability maps for different areas containing the learning outcomes that graduates must acquire throughout their studies. Based on these maps, the presence of ESD in the curriculum of a set of engineering degrees (Sánchez-Carracedo *et al*., 2021b) and education degrees (Sánchez-Carracedo *et al*., 2021a) taught in different Spanish HEIs (Sánchez-Carracedo *et al*., 2021a) is analysed. Presence represents the extent to which the four sustainability competencies appear in university curricula. In this work, the 4 CRUE competencies are used to measure the students' ESD learning.

2. Material and methods

The objective of this work is to analyse and compare the ESD perceived by students of nine engineering degrees and nine education degrees during their university studies, and to determine whether ESD is treated differently or not in both disciplines. These results can be compared with the results of sustainability presence in the degrees to find out to what extent the curricula are achieving their objectives. This objective will be addressed in the future work of the authors, although the preliminary results of a specific degree can be found in Sánchez-Carracedo *et al.* (2021a).

2.1 Research questions

Starting from the previous objective, this paper aims to answer the following questions:

1: Do students in engineering and education degrees consider that they receive the same training in sustainability?

2: Is the sustainability training perceived by students of engineering and education degrees similar in the different domain levels of the learning taxonomy?

3: Is the sustainability training perceived by students homogeneous in the two areas, education and engineering?

4: What is the relationship between the learning perceived by students on completion of their undergraduate studies and the learning that they could have achieved? Do significant differences exist in the relationship found between both variables between engineering and education degrees?

2.2 Instruments

In order to answer these research questions, two instruments are used as a reference:

- The Edinsost sustainability maps of engineering and education degrees (Sánchez Carracedo *et al.*, 2021b; Sánchez-Carracedo *et al.*, 2021a). The four CRUE sustainability competencies are classified into three domain levels using as a taxonomy a version of Miller's pyramid (Miller, 1990) in which the two highest domain levels are considered together: Know, Know how & Demonstrate + Do.

- The questionnaires for education (Sánchez-Carracedo *et al.*, 2021a) and engineering (Sánchez-Carracedo *et al.*, 2021a) degrees. Both questionnaires have undergone a rigorous validation process (Sánchez-Carracedo *et al.*, 2021a), and allow comparison of student perception regarding the learning developed in the four CRUE sustainability competencies.

2.3 Sample

The questionnaires contain the statements of 2624 students from 4 engineering degrees and 4 education degrees:

- Engineering degrees
  - Bachelor's Degree in Informatics Engineering (BDIE)
  - Bachelor's Degree in Mechanic Engineering (BDME)

    - Bachelor's Degree in Chemical Engineering (BDCHE)
    - Bachelor's Degree in Industrial Technologies Engineering (BDITE)
- Education degrees
    - Bachelor's Degree in Social Education (BDSE)
    - Bachelor's Degree in Early Childhood Education (BDECE)
    - Bachelor's Degree in Primary Education (BDPE)
    - Bachelor's Degree in Pedagogy (BDP)

These degrees are taught at 6 Spanish HEIs.

- Universitat Politècnica de Catalunya (UPC)
- Universidad Politécnica de Madrid (UPM)
- Universidad de Sevilla (US)
- Universidad de Cádiz (UCA)
- Universitat Internacional de Catalunya (UIC)
- Universidad de Salamanca (USAL)

Not all degrees are taught at all HEIs. The total sample is made up of 18 degree courses: 9 engineering degrees and 9 education degrees, as shown in Table 1.

Table 1: Degree offered at each university

	UPC	UPM	US	UCA	UIC	USAL
BDIE	x	x	x			
BDME	x		x			
BDCHE		x	x			
BDITE		x	x			
BDSE						x
BDECE				x	x	x
BDPE			x	x	x	x
BDP						x

Table 2 presents the distribution of the students who answered the questionnaire according to their degree and course. The number of students (Abs column) and the percentages they represent in each case are shown. The information of the students has been classified according to whether they are in the first or the fourth year. As can be seen the sample is not balanced, since two-thirds of the students belong to first-year students, while one-third belong to fourth-year students.

Table 2: Distribution of students according to their degree and course.

Course	Engineering		Education		Overall	
	Abs.	%	Abs.	%	Abs.	%
1st	1157	68.79	548	58.17	1705	64.97
4th	525	31.21	394	41.83	919	35.02
Overall	1682	100	942	100	2624	100

2.4 Metodology

Two composite indicators have been constructed to analyse the data collected by the questionnaires. This statistical manipulation technique enables the complexity of the information in the questionnaire questions to be simplified, thus avoiding the problems entailed in a simple aggregation (Saisana and Tarantola, 2002). Furthermore, it allows information to be interpreted and transmitted without loss of reliability, precision and validity (de Vaus, 2002).

The first composite indicator, called "learning increase", is used to measure absolute learning declared by fourth-year students compared to that declared by first-year students. Its construction process is divided into three stages:

1. Exploration of the data matrix: after detecting the presence of missing values and the absence of trends therein, an imputation of the missing values is made by the median (de Vaus, 2002). Asymmetric distributions are then detected and all variables (questionnaire questions) are standardised.

2. Analysis of the unidimensionality and reliability of the data structure: the first objective of this stage is to verify that the questions that will form a composite indicator to measure the same underlying dimension (in the case of the engineering questionnaire, some domain levels are associated to more than one question, which does not happen in the education questionnaire). This is verified by ensuring that all the values of the questions intended for grouping into composite indicators score more than 0.5 in the Kaiser-Meyer-Olkin (KMO) measure (Kaiser and Rice, 1974), and that the Bartlett sphericity test results are significant. The extent to which the answers to the questions grouped in a composite indicator are internally consistent is also studied; that is, whether the questions from the same group tend to generate similar values for each individual. To this end, it is verified that all the groups of questions have a Cronbach alpha coefficient higher than 0.6 (Cronbach, 1951; Loewenthal, 1996). Next, a principal component analysis (PCA) is performed to generate the composite indicators by applying the Kaiser Criterion (Kaiser, 1960): only those principal components whose eigenvalues exceed the value 1 are preserved. In all the composite indicators, competencies, competency units and domain levels, a single valid composite indicator was retained to explain at least 60% of the

variance of the original variables (questions). Finally, the factor scores of the rotated factor matrices as a result of the PCAs are extracted.

3. Rescaling of the composite indicators: the main components obtained in the PCAs are readjusted to the original 0-3 scale. This technique makes it easier to interpret the learning increase, because for all indicators it generates similar and known lower and upper limits, which makes their analysis more intuitive.

The learning increase indicator is calculated using Equation (1), CI being the composite indicator:

$$\frac{CI - min_{CI}}{max_{CI} - min_{CI}} * 3, \qquad (1)$$

Equation 1 can be used to analyse competencies individually, together, or according to their domain levels.

The second indicator, called "learning percentage", measures the relative learning declared by the students; that is, the percentage of learning declared by the students with respect to the learning they could have achieved. This indicator is constructed from the average values of the learning increase indicator according to course, degree, university and area of knowledge. The measurement of the learning percentage is based on comparing the increase in learning declared by fourth-year students (with respect to first-year students) with the learning that the first-year students had yet to acquire. The calculation of the measure at the aggregate level is necessary because the research design is a cross-sectional study and not a panel study (Rafferty *et al.*, 2015). In other words, it can measure the change that has occurred at the aggregate group level, but not the change in individuals themselves.

The learning percentage indicator is calculated using Equation (2), AL_4 being the 4th course university/degree-aggregated learning, and AL_1 the 1st course university/degree-aggregated learning:

$$\frac{AL_4 - AL_1}{3 - AL_1}, \qquad (2)$$

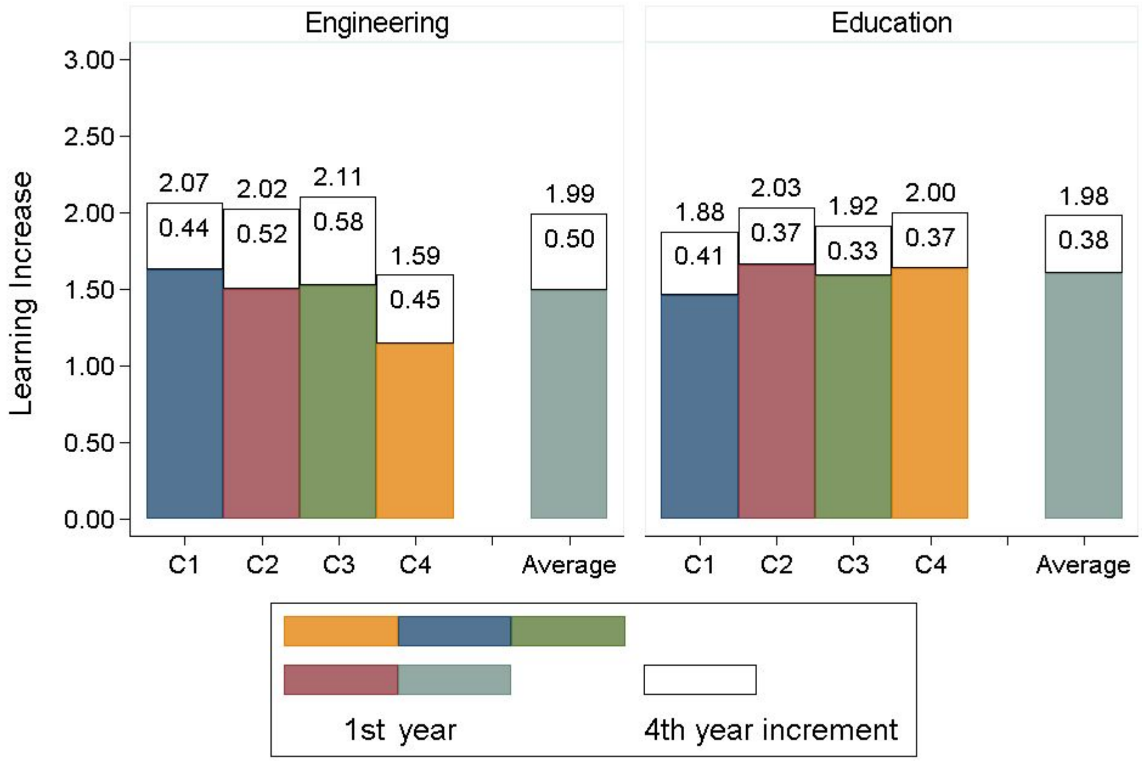
To assess the possible implications of the differences in the number of responses obtained in each degree (see Table 2), a correlational analysis was performed to explore the relationship between the difference in participants from first and fourth years and the two composite indicators of declared learning. The non-parametric test indicates that the difference in observations is not related to the level of learning (rENG-LI = 0.2108, p = ns; rENG-LP = -0.105, p = ns; rEDU-LI = -0.316, p = ns ; rEDU-LP = -0.949; p = ns) for any of the learning indicators in either area of knowledge. Therefore, neither the inequality of the sampling distributions in either area nor the type of study (repeated cross-sectional) have implications that compromise the results of this study.

3. Results and discussion

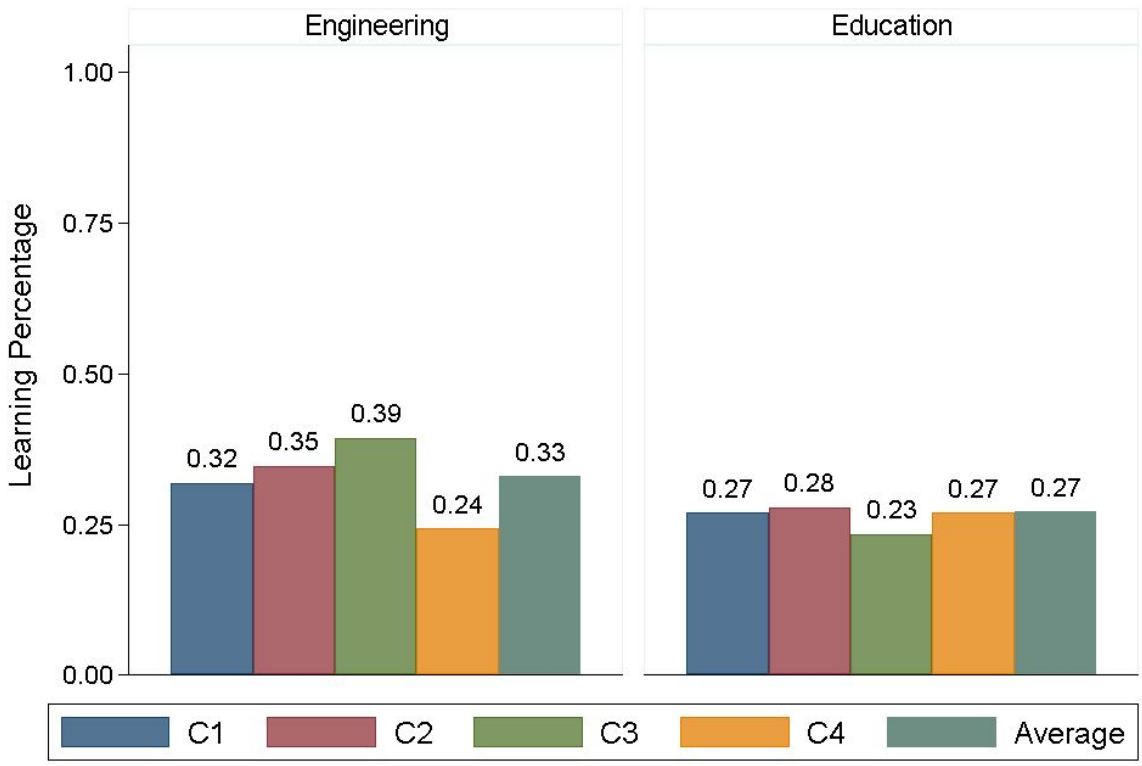
The data enabling the four research questions to be answered are shown in this section in several figures. Figures 1 to 3 are composed of two grouped bar graphs: “a” and “b”. Figures “a” show, on a scale from 0 to 3 (numerical transformation of the Likert scale of the answers to the questions), the value of the first composite indicator, “learning increase”, for first- and fourth-year students in the two areas of knowledge. The graph allows us to see the stated learning differences between first- and fourth-year students in each case. Figures “b” show, on a scale from 0 to 1, the value of the second composite indicator, “learning percentage”.

3.1 Do students in engineering and education degrees consider that they receive the same training in sustainability?

Figure 1 shows the learning declared by students in the fields of engineering and education for each of the four CRUE competencies (C1-C4) and on average, both for the learning increase and for the learning percentage indicators.


Engineering
Education
Learning Increase
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2.07
0.44
2.02
0.52
2.11
0.58
1.59
0.45
1.99
0.50
1.88
0.41
2.03
0.37
1.92
0.33
2.00
0.37
1.98
0.38
C1
C2
C3
C4
Average
1st year
4th year increment

a


Engineering
Education
Learning Percentage
1.00
0.75
0.50
0.25
0.00
0.32
0.35
0.39
0.24
0.33
0.27
0.28
0.23
0.27
0.27
C1
C2
C3
C4
Average

b

Figure 1. Learning declared by engineering and education students in each competency and on average.

Figure 1 (a) shows that, on average, first-year engineering students report having an apprenticeship close to 50% (1.5 out of 3) upon entering university, and fourth-year students report approximately 66% (1.99 out of 3). This learning increase assumes an average learning percentage of 33%, as can be seen in Figure 1 (b).

First-year Education students declare that they have an average learning level of slightly over 50% upon entering university, while fourth-year students declare approximately 66% (1.98 out of 3). This learning increase represents an average learning percentage of 27%.

The average learning percentage in education is lower than that of engineering because the learning reported by fourth-year students is similar in both disciplines, while first-year Education students report having greater learning than engineering students do.

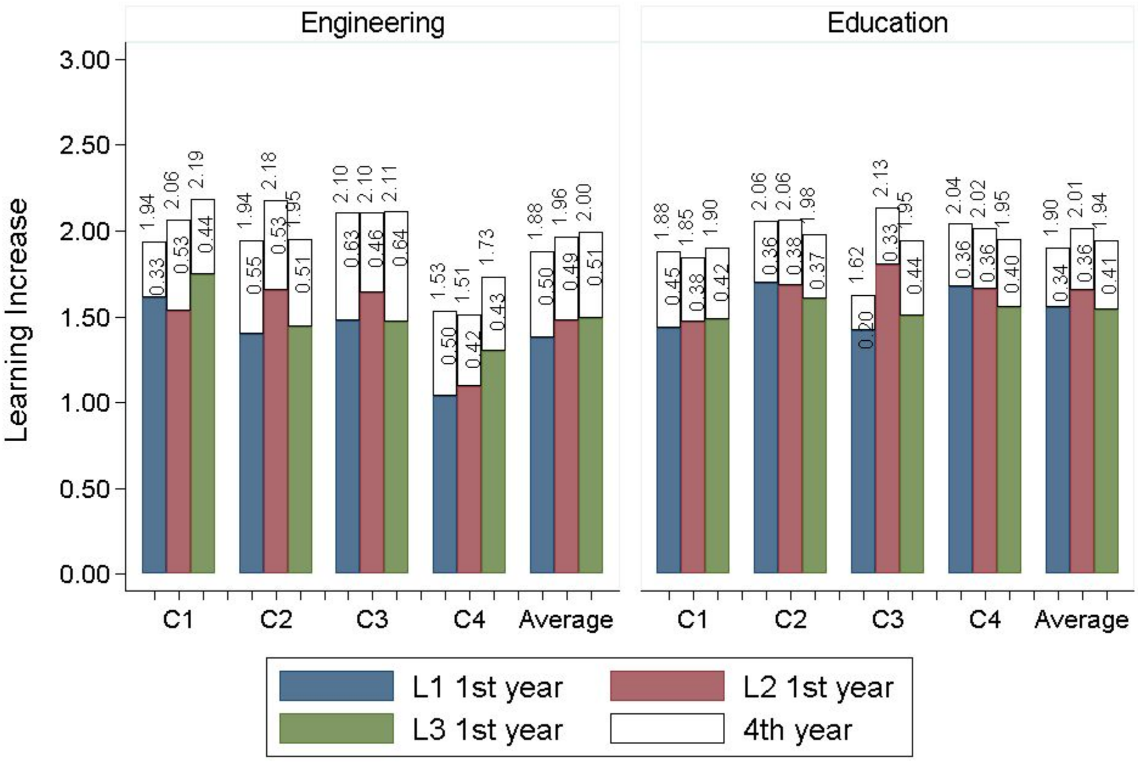
In engineering degrees, C4 (ethics) is the competency in which students report the lowest learning increase (1.59 out of 3) and learning percentage (24%). This result may be related to the fact that topics related to ethics do not usually appear in the courses of some engineering degrees (Miñano *et al.*, 2019). In contrast, C3 (participation in community processes) is the competency in which these same students report the highest learning increase (2.11 out of 3) and learning percentage (39%).

In the education degrees, no great variations are observed in the learning increase and learning percentage declared in the four competencies.

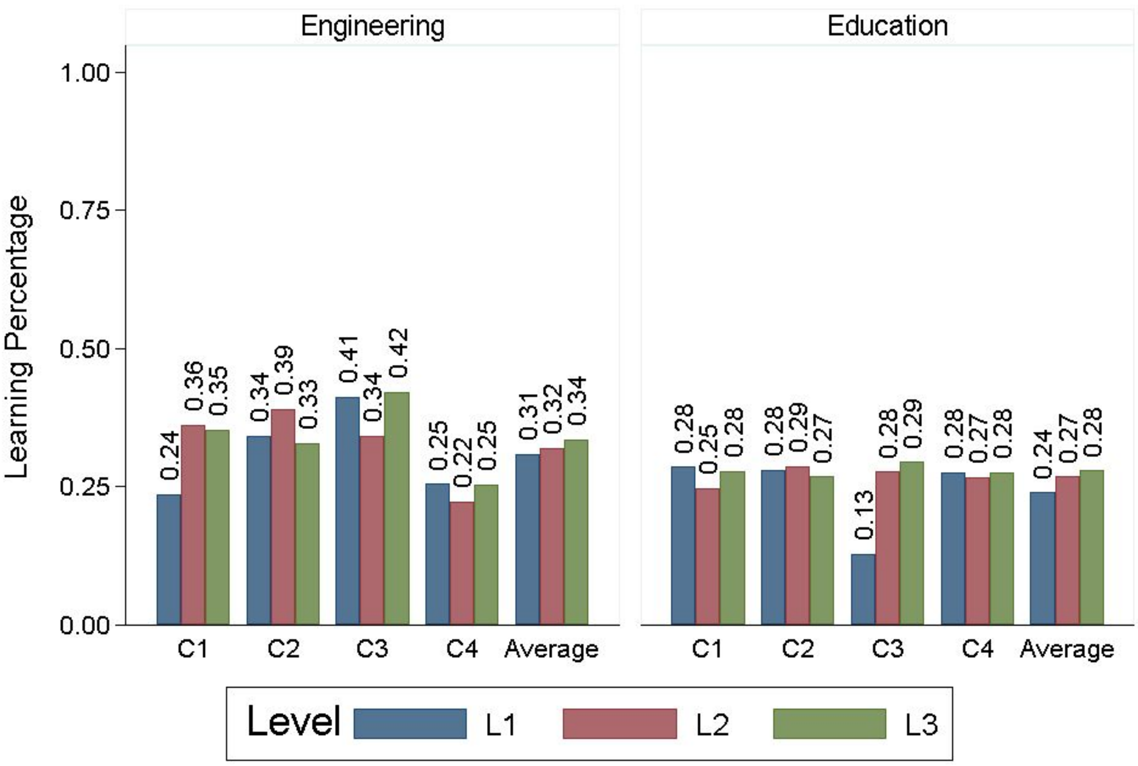
From the analysis of Figure 1, it can be deduced that there are no differences in the final learning achieved by the students of either discipline, with the exception of C4 (ethics), in which engineering students perceive less learning. Given that first-year engineering students report less learning than education students do, it appears that engineering students perceive that they learn more than education students, with the exception of ethics.

3.2 Is the sustainability training perceived by students of engineering and education degrees similar in the different domain levels of the learning taxonomy?

Figure 2 shows the learning declared by engineering and education students at each domain level (L1: know, L2: know how and L3: demonstrate + do) for each competency and on average.


Engineering
Education
Learning Increase
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.94 2.06 2.19
0.33 0.53 0.44
1.94 2.18 1.95
0.55 0.53 0.51
2.10 2.10 2.11
0.63 0.46 0.64
1.53 1.51 1.73
0.50 0.42 0.43
1.88 1.96 2.00
0.50 0.49 0.51
1.88 1.85 1.90
0.45 0.38 0.42
2.06 2.06 1.98
0.36 0.38 0.37
1.62 2.13 1.95
0.20 0.33 0.44
2.04 2.02 1.95
0.36 0.36 0.40
1.90 2.01 1.94
0.34 0.36 0.41
C1
C2
C3
C4
Average
L1 1st year
L2 1st year
L3 1st year
4th year

a


Engineering
Education
Learning Percentage
1.00
0.75
0.50
0.25
0.00
0.24 0.36 0.35
0.34 0.39 0.33
0.41 0.34 0.42
0.25 0.22 0.25
0.31 0.32 0.34
0.28 0.25 0.28
0.28 0.29 0.27
0.13 0.28 0.29
0.28 0.27 0.28
0.24 0.27 0.28
C1
C2
C3
C4
Average
Level
L1
L2
L3

b

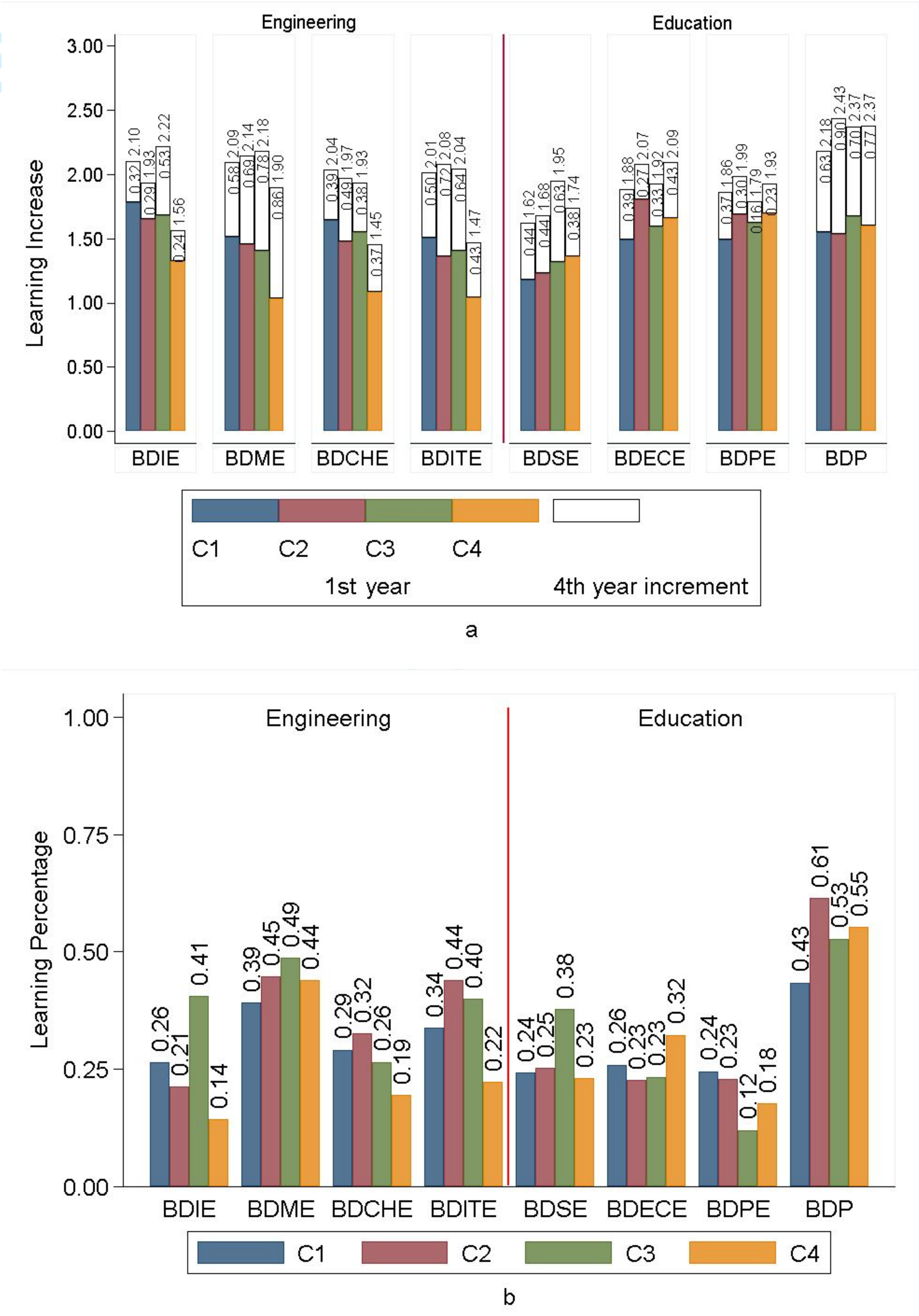
Figure 2. Learning declared by engineering and education students in each domain level for each competency and on average.

In engineering degrees, mean learning is higher at the highest levels of the taxonomy (L1 <L2 <L3), both in learning increase and learning percentage. These results are in line with a teaching in engineering that emphasises the development of more applicative tasks (Tejedor *et al.*, 2018). C4 (ethics) is the competency with the lowest learning in the three domain levels, not exceeding 25% of learning percentage in any of them. Therefore, the low learning of C4 noted in Figure 1 is not due to a marked absence of learning at any particular domain level. On the other hand, C3 (participation in community processes) is the only competency in which the graduates declare an almost identical learning increase in the three domain levels. Thus, C3 is the competency in which engineering students declare greater learning (see Figure 1) and, in addition, the learning increase is uniform. In applied studies such as engineering degrees, the L3 level of each competency is expected to develop more than the L1 and L2 levels, as in C1 and C4. It is striking, therefore, that students perceive greater learning at the L2 level in the competency C2 (sustainable use of resources). Perhaps this is because, traditionally, engineers have not been concerned with where and how resources are obtained, but rather with what to do with them. Therefore, when this competency is introduced in engineering degrees, it is still done in a very applied way (Miñano *et al.*, 2019).

In education degrees, students perceive homogeneous learning at the domain levels of all competencies, except for level L1 of competency C3 (participation in community processes), in which students report learning significantly less, both in learning increase (1.62 out of 3) and in learning percentage (13%). This low value of the L1 level of C3 implies that C3 is the competency with the lowest learning percentage on average (23%) in education degrees (see Figure 1 (b)).

3.3 Is the sustainability training perceived by students homogeneous in the two areas, education and engineering?

Figure 3 shows the learning declared by engineering and education students in each competency, broken down according to the different degrees analysed. The abbreviations used in the figure are defined in the 'Material and methods' Section.



Engineering
Education
Learning Increase
BDIE
BDME
BDCHE
BDITE
BDSE
BDECE
BDPE
BDP
C1
C2
C3
C4
1st year
4th year increment
a
Learning Percentage
b

Figure 3. Learning declared by engineering and education students in each competency, broken down by degrees.

Figure 3a shows that, in all engineering degrees (the 4 degrees on the left of the figure), C4 (ethics) is the competency in which students declare less learning, both upon entering and leaving university. This is, therefore, a common problem for all engineering degrees. However, it is worth highlighting the learning percentage declared by the BDME students (44%) in C4, which is even higher than the learning declared by these same students for C1 (39%) and similar to C2 (45%). Furthermore, BDME students are the only ones who declare learning percentages in the four sustainability competencies higher than the average learning percentage for the engineering area: 33% (see Figure 1). These good results of the BDME may be related to the greater learning that their students declare as having in aspects intended to improve the common good of society, such as accessibility, ergonomics and safety, among others.

Although C3 (participation in community processes) is the competency that presents the best average results in engineering degrees (Figure 1), analysis by degrees reveals that only BDIE and BDME students claim to learn more in this competency. On the other hand, the absence of environmental issues in the BDIE curriculum (Miñano *et al.*, 2019) would explain the low learning of C2 (Sustainable use of resources) declared by students of this degree.

Regarding the education degrees, it seems that each one focuses on a different competency. In the BDSE, the learning percentage of competency C3 (participation in community processes) stands out; in the BDECE C4 (ethics) stands out; in the BDPE C1 (critical contextualization of knowledge) stands out, and in the BDP C2 (Sustainable use of resources) is the most salient. It is worth pointing out the results declared by the students of the BDP, the only degree with learning values higher than the average values. This result is consistent with other studies (Sánchez-Carracedo *et al.*, 2021a), in which it is highlighted that this fact is due to the model used in the BDP for introducing sustainability competencies.

These results are in line with other studies (Kim and Sax, 2011; Pike and Killian, 2001) that show that the development of cognitive skills in students and their learning varies significantly according to the academic specialty they are studying, influenced by the processes of interaction with teachers.

3.4 What is the relationship between the learning perceived by students on completion of their undergraduate studies and the learning that they could have achieved? Do significant differences exist in the relationship found between both variables between engineering and education degrees??

Figure 4 shows the correlation between the learning percentage indicator (X-axis) and the learning declared by the fourth-year students (Y-axis, 4th year learning) for each of the four sustainability competencies in the two areas of knowledge. One line is displayed for education degrees (segmented line) and another line for engineering degrees (continuous line).

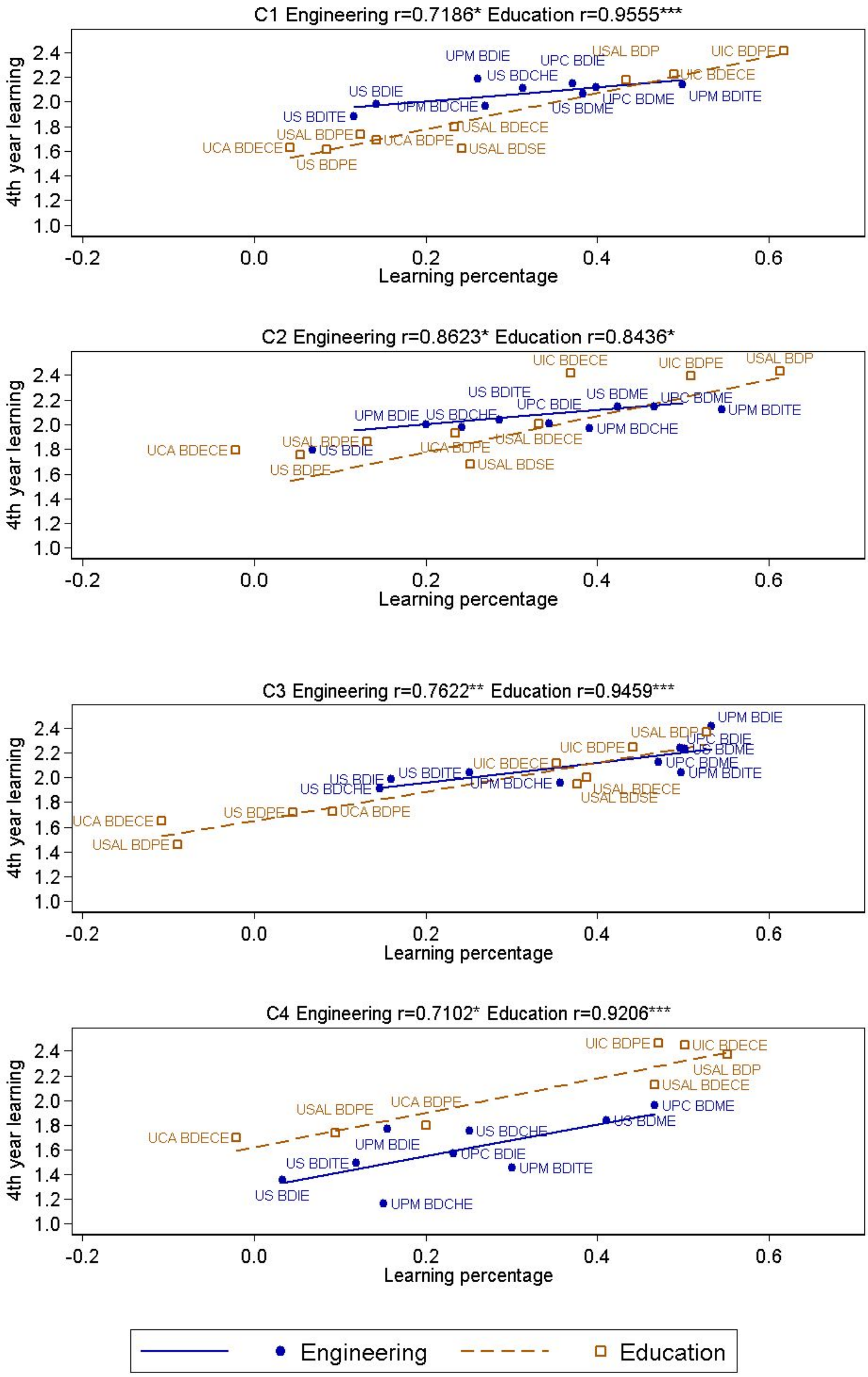

C1 Engineering r=0.7186* Education r=0.9555***
4th year learning
Learning percentage
C2 Engineering r=0.8623* Education r=0.8436*
4th year learning
Learning percentage
C3 Engineering r=0.7622** Education r=0.9459***
4th year learning
Learning percentage
C4 Engineering r=0.7102* Education r=0.9206***
4th year learning
Learning percentage
Engineering
Education

Figure 4. Correlation between the learning percentage and the learning declared by the fourth-year students.

The relationship between these two variables is not a dependency relationship, since the learning percentage depends not only on the learning declared by the fourth-year students, but also on the learning declared by the first-year students. In any case, it is a direct relationship, as can be identified by observing the trend lines generated in the four graphs in Figure 4. The correlation is very high in all cases (* $p < .5$; ** $p < .01$):

- C1: 0.7186 * for Engineering and 0.9555 ** for Education
- C2: 0.8623 ** for Engineering and 0.8436 ** for Education
- C3: 0.7622 * for Engineering and 0.9459 ** for Education
- C4: 0.7102 * for Engineering and 0.9206 ** for Education

*p< .5; **p< .01

The trend lines show a similar behaviour in the C1, C2 and C3 competencies. The low slope of the lines of the engineering degrees indicates that students declare very similar learning at the end of their studies in each of the three competencies, regardless of the degree or university. Therefore, in general, students who report less preparation in the first year learn more throughout their studies. On the other hand, the higher slope of the lines in the education degrees indicates that the final learning declared by the students is highly dependent on the degree and the university. In the main, students who report the most learning at the end of their studies are also those who have learned the most. This is also found in the competency C4 (ethics) for the two disciplines. It should be noted that, in the case of C4, the two lines are almost parallel, but the distance between them clearly shows how the education degrees develop ethics more deeply than the engineering degrees, as shown in Figures 1 and 3.

The concentration of degrees along the trend line must also be considered. There is a wide dispersion of degrees in competencies C1 (Critical contextualization of knowledge) and C2 (Sustainable use of resources), both in education and engineering degrees, which suggests that each degree follows its own criteria for developing these competencies.

On the other hand, there is a high concentration of degrees at the top of the trend line for engineering degrees in C3 (Participation in community processes), and the same is found in C4 (Ethics) with education degrees. This seems to indicate that Participation in community processes is closely related to engineering degrees, and Ethics to education degrees.

It is interesting to note that, in all competencies, degrees are found at the ends of the trend lines, which shows great variability in learning. The presence of two outliers in the competency C2 should also be noted: the BDECE of the UCA and the UIC. In both cases, first-year students declare high learning compared to that declared by other first-year students from other degrees and/or universities. This could be due to the Kruger-Dunning effect (Kruger and Dunning, 1999), according to which 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. The other competencies do not present relevant outliers.

In engineering degrees, it appears that students of the different degrees have a learning goal for each competency, which they achieve in all degrees regardless of the level they declared at the beginning of their studies. On the other hand, education degrees seem to have no specific goals for the same competency, and the degrees in which students claim to learn more (in percentage) are those that achieve the best results in each competency. This last observation is also valid for the competency C4 (ethics) of engineering degrees, which corroborates the observation made previously that, in the case of ethics, the final learning achieved by students of the different degrees is not homogeneous, but largely depends on how ethics is developed in each degree. This is not found with the other three competencies in engineering degrees.

3.5 Implications for research, practice and society

This research aims to show the differences that exist in the perception that students of engineering and education degrees have about their own learning in sustainability competencies. Eighteen curricula of four engineering and four education degrees, linked to the (Edinsost) project, have been analysed. The differences found have already been made explicit in the previous sections, but there is a gap between theoretical discourse and professional practice.

In education degrees, Kilpatrick (1990) already warned that “there does seem to be something wrong with having one group decide what to do and the other do it” (p. 35), referring to the mismatches found between theoretical research on the part of teacher educators and the professional practice that they adopt a posteriori. The very complexity of the classroom as a dynamic social reality, in constant change and evolution (Colom, 2002), with which teachers interact is to a large extent the reason for these imbalances. Korthagen (2001) advocates an alternation between action and reflection in teacher training as a framework for addressing this problem. In this sense, the authors consider that the curricular training practice seminars conducted in education degrees are an opportunity to establish this type of dialogic approach, since they encourage students to adopt a critical educator-researcher attitude that questions educational processes on the basis of contributions from educational research.

This gap between theory and practice is no less pronounced in engineering degrees. In general, scientific knowledge is conceived for the benefit of society and the common good. However, in technology-related degrees, the training of professionals is often based on concepts far removed from human activity (Brito-*Vallina et al*., 2011). Skovsmose (1994) advocates the inclusion of modelling processes in technological training as an instrument to enable the development of an ethical-reflective “knowing”. A modelling process involves different types of languages: from a more natural and human language to a more scientific language that models a problematic reality. Addressing the problems and uncertainties associated with the transitions between these two types of languages, natural and scientific, would favour the development of an ethical competency (Skovsmose, 1994) that the authors have found to be very poorly developed in engineering degrees.

On the other hand, in both education and engineering degrees, final degree projects also provide an opportunity to promote teaching and learning in aspects related to sustainability.

Students have the chance to demonstrate that they have learned to reflect on the consequences of their actions as professionals, and to consider how societies could adapt to ensure a more sustainable future (Longhurst *et al.*, 2014).

In relation to recent empirical approaches to the study of the presence of sustainability in the Spanish university system, the authors found similarities with the main findings of this paper. On the one hand, it is observed that a great disparity exists in the development of sustainability competencies between different education degrees (ommited for blind review). On the other hand, the absence of ethical issues in engineering degrees is an issue previously pointed out by other studies (Miñano Rubio *et al.*, 2019).

Finally, it is vitally important that students should receive training in inclusive educational strategies based on the principles and guidelines of the Universal Design for Learning (UDL). UDL proposes a practical application framework in the democratised classroom (Rose and Meyer, 2000) that is organized based on three principles: (1) provide multiple forms of representation, (2) of action and expression, and (3) of involvement. UDL is closely related to Open Educational Resources (OER). Indeed, one of the objectives of the project in which the authors are currently engaged is the creation of a multidisciplinary resource bank to assist teachers of both education and engineering degrees in the task of introducing ESD into their subjects.

3.6 Research limitations

This work presents several limitations that must be taken into account when evaluating the results.

- First, only 9 engineering degrees and 9 education degrees taught at 6 universities have been studied. To draw definitive conclusions, a larger sample including more degrees and more universities is needed.
- Second, this is a study of the repeated cross-sectional type, since the samples from each course do not include the same subjects or are collected at different times (Bryman, 2016). Therefore, the observed improvement should be interpreted as an overall improvement. It is not possible to determine whether this improvement occurs with the surveyed students. Although this is a longitudinal study, it cannot be ruled out that other factors may have influenced learning. The results presented reflect the learning increase on average, but not the average learning increase (this would require the surveys to have been answered by the same students when they were in the first and fourth years of the course).
- Third, students have voluntarily responded to the survey (they have not been randomly selected).
- Fourth, the survey measures students' perception of their own sustainability competencies, not their actual knowledge.
- Finally, the instruments used to measure the perception of education and engineering students are different. Although they are constructed with the same criteria and follow the same validation process, this fact could also influence the results.

4. Conclusions

This article analyses and compares the perception of students' sustainability learning in nine engineering degrees and nine education degrees. The study may assist in helping HEIs to determine how to improve the sustainability competencies that future graduates must acquire, since it is essential to train responsible and committed graduates in order to progress towards a more sustainable world.

Globally, the average learning percentage in sustainability competencies is 33% in engineering and 27% in education. The difference is fundamentally because education students claim to have more sustainability knowledge upon entering university than engineering students. However, the average learning increase that students declare at the end of their studies in both areas of knowledge is similar, around 66%. In other words, graduates from both areas of knowledge claim to achieve the same level of sustainability, regardless of the initial training with which they entered the university.

The analysis by competencies shows that, on average, engineering students report greater learning than education students in all competencies except C4 (Ethics). In engineering degrees, C3 (participation in community processes) is the competency in which students declare not only the greatest learning increase and learning percentage, but is also the competency that shows the most homogeneity in the three domain levels. Conversely, in education degrees the low level of learning declared by students at the L1 level of the C3 competency stands out. The analysis of the results by degrees confirms that the learning that students claim to achieve in one or another competency is influenced by the disciplinary content that students receive throughout their studies (Pike and Killian, 2001).

The analysis of the correlation between the learning percentage and the final learning declared by the fourth-year students reveals that engineering degrees achieve fairly homogeneous results in the C1, C2 and C3 competencies, regardless of the learning declared by the students at the beginning of their studies. The same is not found with the competency C4 (Ethics), in which the final learning of engineering students depends largely on the degree they take. In education degrees, however, this fact occurs in the four competencies, which seems to indicate that there are no clearly defined goals regarding sustainability competencies in education degrees.

Finally, this work does not intend to generalise the results presented, but rather to understand and interpret the problem in the context where it occurs in order to evaluate it. However, it is foreseeable that the findings of this study could be transferred to similar contexts or settings. In this sense, the methodological proposal of this research allows this study to be replicated in other degrees in order to compare the results with those presented here.

Therefore, the authors would like to propose a set of recommendations that can serve as a basis for improving the embedding of ESD in university curricula:

- To improve the students' sustainability competencies, it is necessary to first improve those of teachers, for example, by scheduling training courses for all teachers interested in including ESD in their subjects.
- Teachers who include ESD in their subjects should update the learning guide and communicate it to the person in charge of the degree.

- The authors consider that it is very important to appoint a person in charge of ESD in the curriculum, who coordinates the teachers and who has a global vision of the changes done in the subjects, so that all the Learning Outcomes of the sustainability map are covered. In this sense, it is necessary to monitor the improvements in ESD that are made in the curriculum.
- It is also convenient to monitor the progress in ESD of students by, for example, conducting annual surveys to students who finish the degree.
- Finally, it would be interesting to relate the data of the improvements registered in the curriculum with the improvement declared by the students, to check whether the subjects are achieving their objectives in ESD.

References

Adams, C.A. (2013), "Sustainability reporting and performance management in universities: Challenges and benefits", *Sustainability Accounting, Management and Policy Journal*, Vol. 4 No. 3, pp.384-392.

Aginako, Z., Peña-Lang, M.B., Bedialauneta, M.T. and Guraya, T. (2021), "Analysis of the validity and reliability of a questionnaire to measure students' perception of inclusion of sustainability in engineering degrees", *International Journal of Sustainability in Higher Education*, Vol. ahead-of-print No. ahead-of-print.

Aleixo, A.M., Leal, S. and Azeiteiro, U.M. (2018), "Conceptualization of sustainable higher education institutions, roles, barriers, and challenges for sustainability: An exploratory study in Portugal", *Journal of Cleaner Production*, Vol. 172, pp.1664-1673.

Aleixo, A.M, Azeiteiro, U.M. and Leal, S. (2020), "Are the Sustainable Development Goals being implemented in the Portuguese Higher Education Formative Offer?", *International Journal of Sustainability in Higher Education*, Vol. 21, pp.336-352.

Amara, A.R., Rodrigues, E., Rodrigues Gaspar, A. and Gomes, A. (2020), "A review of empirical data of sustainability initiatives in university campus operations", *Journal of Cleaner Production*, Vol. 250, pp.119558.

Barth, M., Godemann, J., Rieckmann, M. and Stoltenberg, U. (2007), "Developing key competencies for sustainable development in higher education", *International Journal of Sustainability in Higher Education*, Vol. 8 No. 4, pp.416-430.

Brito-Vallina, M.L., Alemán-Romero, I., Fraga-Guerra, E., Para-García, J.L. and Arias-de Tapia, R.I. (2011), "Papel de la modelación matemática en la formación de los ingenieros", *Ingeniería Mecánica*, Vol. 14 No. 2, pp.129-139.

Bryman, A. (2016), *Social research methods*, fifth ed., Oxford university press, United Kingdom, UK.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J. and Mitchell, R.B. (2003), "Knowledge systems for sustainable development", *Proceedings of the*

National Academy of Sciences of the United States of America, Vol. 100 No.14, pp.8086–8091.

Colom, A. (2002), *La (de) construcción del conocimiento pedagógico*, Paidós, Barcelona, España.

Cronbach, L.J. (1951), “Coefficient alpha and the internal structure of tests”, *Psychometrika*, Vol. 16, pp.297–334.

CRUE (2012), “Directrices para la sostenibilización curricular”, available at: https://redcampussustentable.cl/wp-content/uploads/2018/03/3-Directrices_Sosteniblidad_Crue2012.pdf (accessed 31 September 2020).

de la Torre, E.M., Rossi, F. and Sagarra, M. (2019), “Who benefits from HEIs engagement? An analysis of priority stakeholders and activity profiles of HEIs in the United Kingdom”, *Studies in Higher Education*, Vol. 44 No. 12, pp.2163-2182.

de Vaus, D.A. (2002), *Surveys in Social Research*, Allen & Unwin, Crows Nest, Australia.

Farinha, C.S., Azeiteiro, U. and Caeiro, S.S. (2018), “Education for sustainable development in Portuguese universities: The key actors’ opinions”, *International Journal of Sustainability in Higher Education*, Vol. 19 No. 5, pp.912-941.

Kaiser, H.F. (1960), “The Application of Electronic Computers to Factor Analysis”, *Educational and Psychological Measurement*, Vol. 20 No. 1, pp.141–151.

Kaiser, H. F. and Rice, J. (1974), “Little Jiffy, Mark IV”, *Educational and Psychological Measurement*, Vol. 34 No. 1, pp.111–117.

Korthagen, F., Kessels, J., Koster, B., Lagerwerf, B. and Wubbels, T. (2001), *Linking practice and theory: The pedagogy of realistic teacher education*, Lawrence Elbaum Associates, London, England.

Kilpatrick, J. (1990), “Change and stability in research in mathematics education”, *The Mathematics Educator*, Vol. 1, pp.107-121.

Kim, Y.K. and Sax., L.J. (2011), “Are the effects of student–faculty interaction dependent on academic major? An examination using multilevel modeling”, *Research in Higher Education*, Vol. 52 No. 6, pp.589-615.

Kruger, J. and Dunning, D. (1999), “Unskilled and unaware of it: How difficulties in recognizing one’s own incompetence lead to inflated self-assessments”, *Journal of Personality and Social Psychology, Vol.* 77 No.6, pp.1121–1134.

Leal Filho, W., Pallant, E., Enete, A., Richter, B. and Brandli, L. L. (2018), “Planning and implementing sustainability in higher education institutions: an overview of the difficulties and potentials”, *International Journal of Sustainable Development & World Ecology*, Vol. 25 No. 8, pp.713-721.

Leal Filho, W., Eustachio, J.H.P.P., Caldana, A.C.F., Will, M., Lange Salvia, A., Rampasso, I.S., Anholon, R., Platje, J. and Kovaleva, M. (2020), "Sustainability Leadership in Higher Education Institutions: An Overview of Challenges", *Sustainability*, Vol. 12 No. 9, pp.3761.

Leicht, A., Heiss., J. and Byun, W.J. (2018), "Issues and trends in education for sustainable development", available at: https://unesdoc.unesco.org/ark:/48223/pf0000261445 (accessed 31 September 2020).

Loewenthal, K.M. (1996), *An introduction to psychological tests and scales*, UCL Press, London, United Kingdom.

Longhurst, J., Bellingham, L., Cotton, D., Isaac, V., Kemp, S., Martin, S., Peters, C., Robertson, A., Ryan, A., Taylor, C. and Tilbury, D. (2014), "Education for Sustainable Development: Guidance for UK Higher Education Providers", available at: https://uwe-repository.worktribe.com/output/816817/education-for-sustainable-development-guidance-for-uk-higher-education-providers (accessed 31 March 2021).

Lozano, R. (2011), "The state of sustainability reporting in universities", *International Journal of Sustainability in Higher Education*, Vol. 12 No. 1, pp.67-78.

Miller, G.E. (1990), "The Assessment of Clinical Skills/Competence/Performance", available at: http://winbev.pbworks.com/f/ Assessment.pdf (accessed 31 September 2020).

Miñano Rubio, R., Uribe, D., Moreno-Romero, A.M. and Yáñez, S. (2019), "Embedding sustainability competences into engineering education. The case of informatics engineering and industrial engineering degree programs at Spanish universities", *Sustainability*, Vol. 11 No. 20, pp.5832.

Pike, G.R. and Killian, T.S. (2001), "Reported gains in student learning: Do academic disciplines make a difference?", *Research in Higher Education*, Vol. 42 No. 4, pp.429-454.

Poza-Vilches, F., López-Alcarria, A. and Mazuecos-Ciarra, N. (2019), "A professional competences' diagnosis in education for sustainability: A case study from the Standpoint of the Education Guidance Service (EGS) in the Spanish Context", *Sustainability*, Vol. 11 No. 6, pp.1568.

Qablan, A. (2018), "Building capacities of educators and trainers", in Leicht, A., Heiss, J. and Byun, W.J. (Eds.), *Issues and trends in education for sustainable development*, UNESCO, Paris, pp.133-156.

Quelhas, O.L.G., Lima, G.B.A., Ludolf, N.V.-E., Meiriño, M.J., Abreu, C., Anholon, R., Vieira Neto, J. and Rodrigues, L.S.G. (2019), "Engineering education and the development of competencies for sustainability", *International Journal of Sustainability in Higher Education*, Vol. 20 No. 4, pp. 614-629.

Rafferty, A., Walthéry, P. and King-Hele, S. (2015), "Analysing change over time: repeated crosssectional and longitudinal survey data", available at: https://www.ukdataservice.ac.uk/media/455362/changeovertime.pdf (accessed 31 September 2020).

Rieckmann, M. (2012), “Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?”, *Futures*, Vol. 44 No. 2, pp.127-135.

Rose, D., and Meyer, A. (2000), “The Future Is in the Margins: The Role of Technology and Disability in Educational Reform”, available at: https://files.eric.ed.gov/fulltext/ED451624.pdf (accessed 31 March 2021).

Saisana, M., Tarantola, S. (2012) “State-of-the-Art Report on Current Methodologies and Practices for Composite Indicator Development”, available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.402.5612&rep=rep1&type=pdf (accessed 31 September 2020).

Sales de Aguiar, T.R. and Paterson, A. S. (2018), “Sustainability on campus: knowledge creation through social and environmental reporting”, *Studies in Higher Education*, Vol. 43 No. 11, pp.1882-1894.

Sánchez-Carracedo, F., Moreno-Pino, F. M., Romero-Portillo, D., & Sureda, B. (2021a). Education for sustainable development in Spanish university education degrees. Sustainability, 13(3), 1467.

Sánchez-Carracedo, F., Sureda, B., Moreno-Pino, F. M., & Romero-Portillo, D. (2021b). Education for Sustainable Development in Spanish engineering degrees. Case study. Journal of Cleaner Production, 294, 126322.

Shephard, K. and Furnari, M. (2012), “Exploring what university teachers think about education for sustainability”, *Studies in Higher Education*, Vol. 38 No. 10, pp.1577-1590.

Skovsmose, O. (1994). *Towards a philosophy of critical mathematics education,* Kluwer Academic Publishers, Dordrecht, Netherlands.

Stephens, J.C. and Graham, A.C. (2010), “Toward an empirical research agenda for sustainability in higher education: Exploring the transition management framework”, *Journal of Cleaner Production*, Vol. 18 No. 7, pp.611–618.

Tejedor, G., Segalas, J. and Rosas-Casals, M. (2018), “Transdisciplinarity in higher education for sustainability: How discourses are approached in engineering education”, *Journal of Cleaner Production*, Vol. 175, pp.29-37.

UNECE (2012), “Learning for the future. Competences in education for sustainable development”, available at: https://unece.org/fileadmin/DAM/env/esd/ESD_Publications/Competences_Publication.pdf (accessed 31 September 2020).

UNESCO (2014), “Shaping the future we want. United Nations Decade of Education for Sustainable Development (2005-2014)”, available at: https://sustainabledevelopment.un.org/content/documents/1682Shaping%20the%20future%20we%20want.pdf (accessed 31 September 2020).

Wiek, A., Withycombe, L. and Redman, C.L. (2011), “Key competencies in sustainability: a reference framework for academic program development”, *Sustainability Science*, Vol. 6, pp.203-218.

Wiek, A., Bernstein, M., Foley, R., Cohen, M., Forrest, N., Kuzdas, C., Kay, B. and Withycombe Keeler, L. (2015), “Operationalising competencies in higher education for sustainable development”, in Barth, M., Michelsen, G., Rieckmann, M. and Thomas, I. (Eds.), *Routledge Handbook of Higher Education for Sustainable Development*, Routledge, London, pp.241-260.

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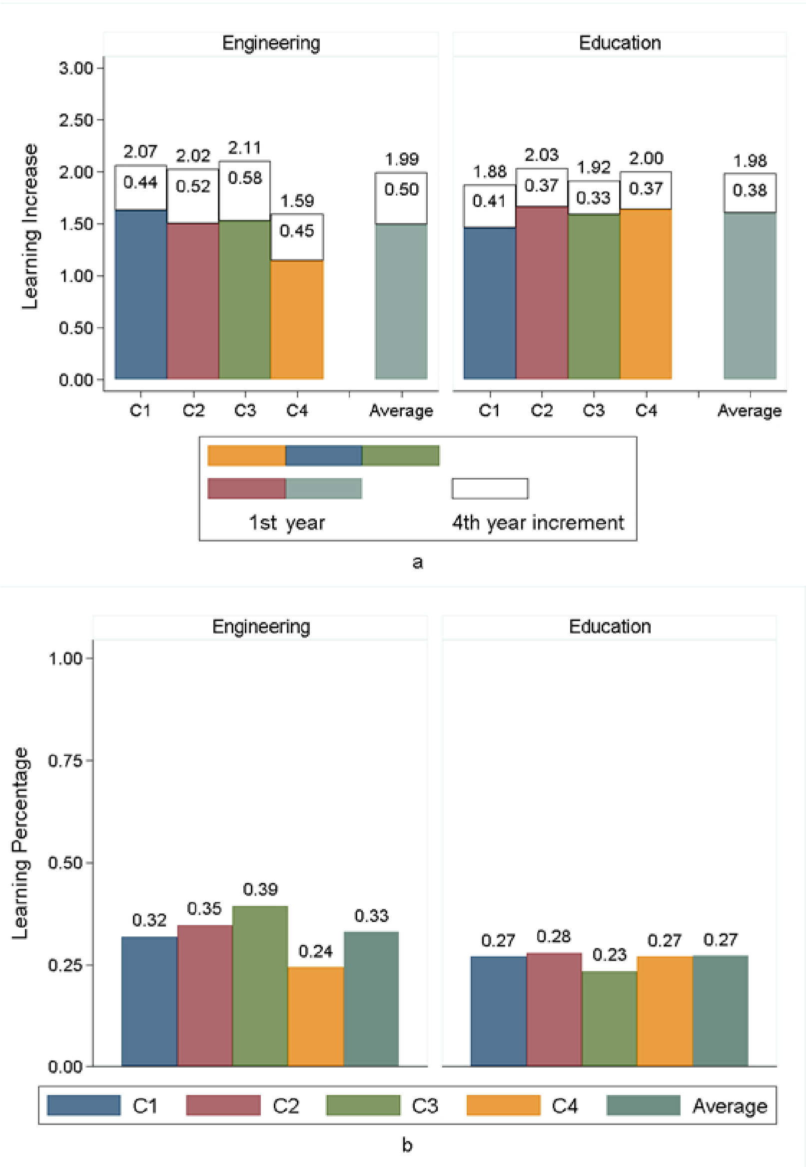

Figure 1. Learning declared by engineering and education students in each competency and on average.

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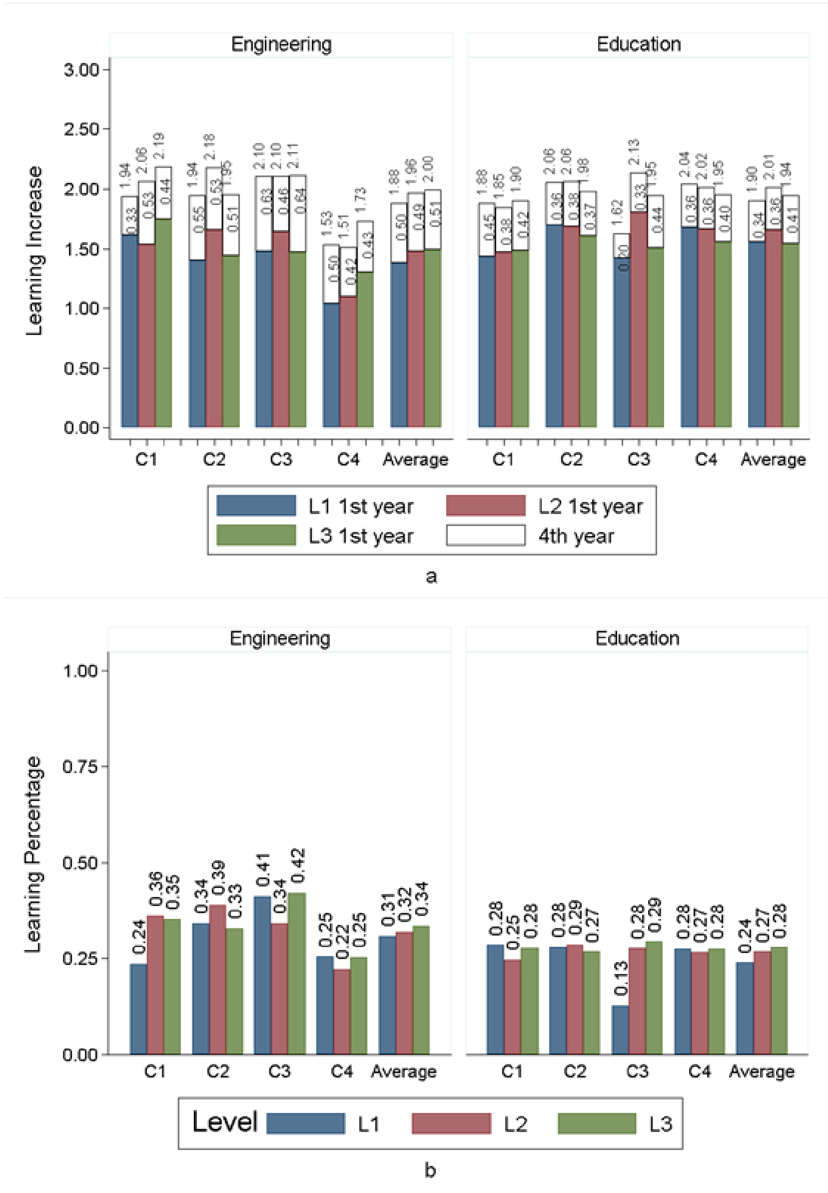

Figure 2. Learning declared by engineering and education students in each domain level for each competency and on average.

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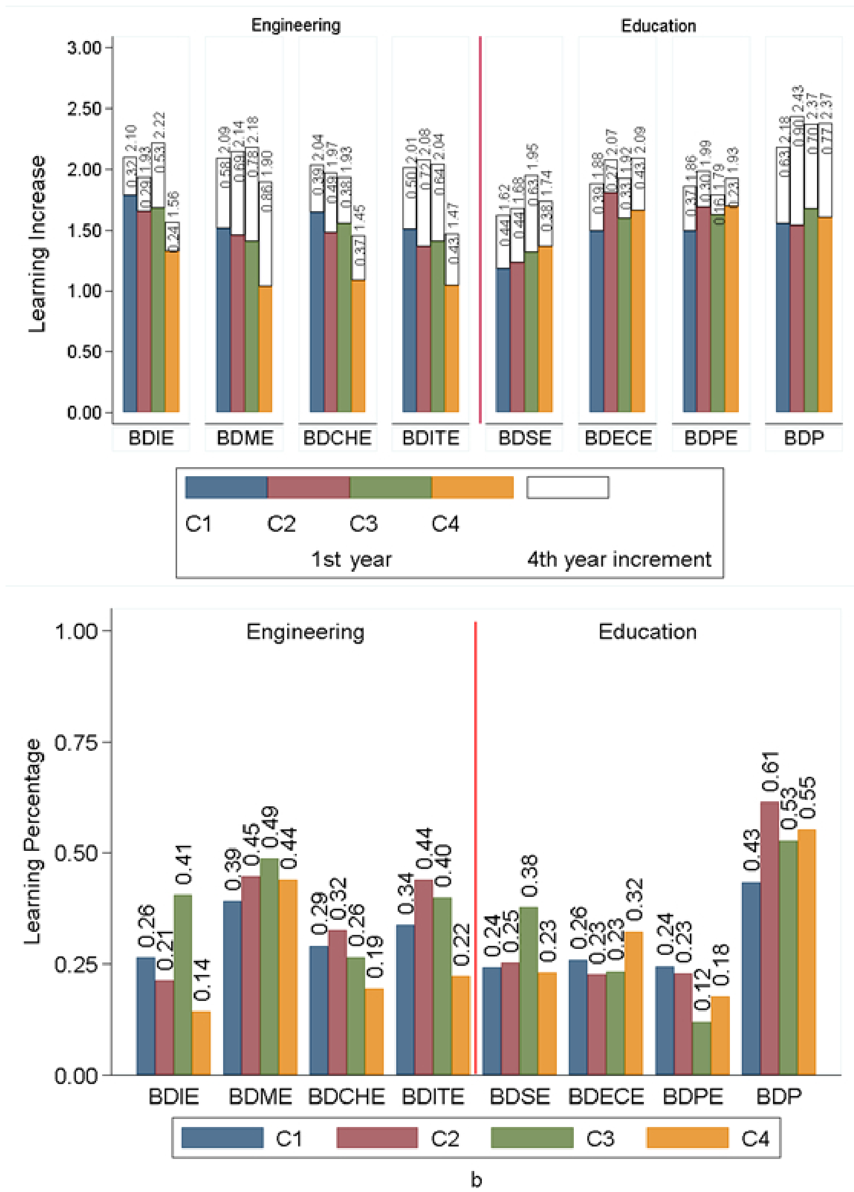

Figure 3. Learning declared by engineering and education students in each competency, broken down by degrees.

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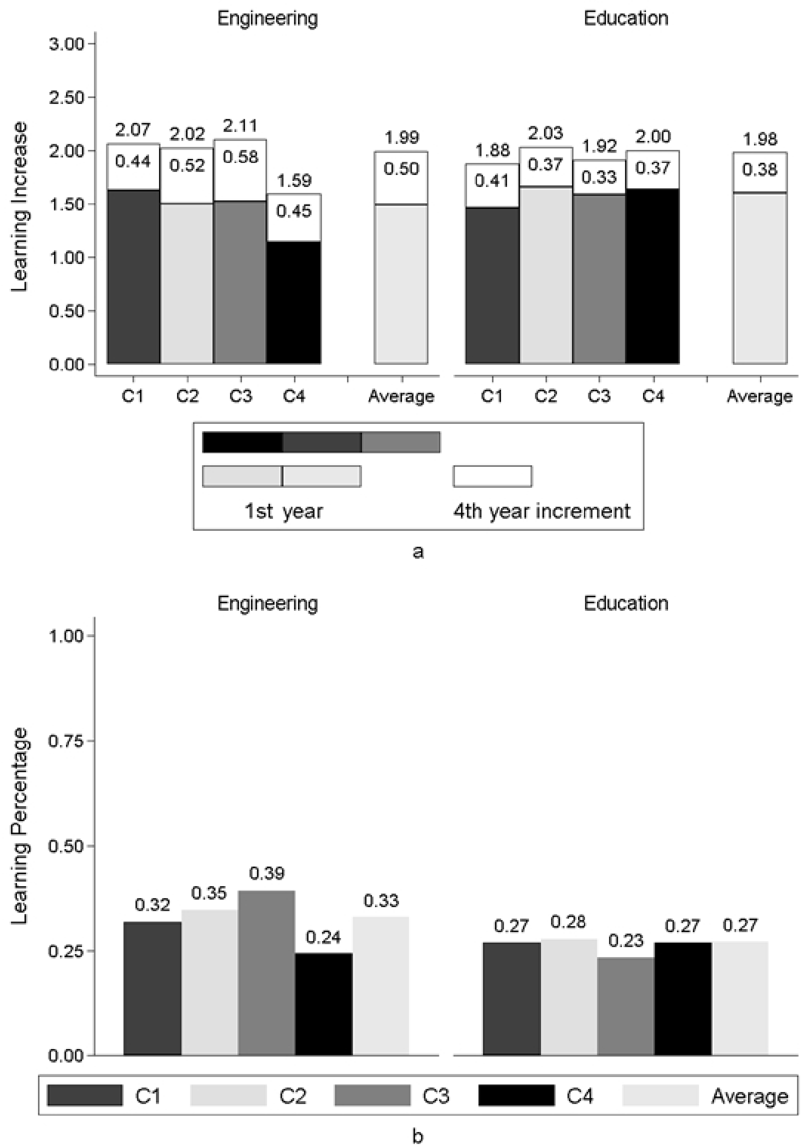

Figure 1. Learning declared by engineering and education students in each competency and on average.

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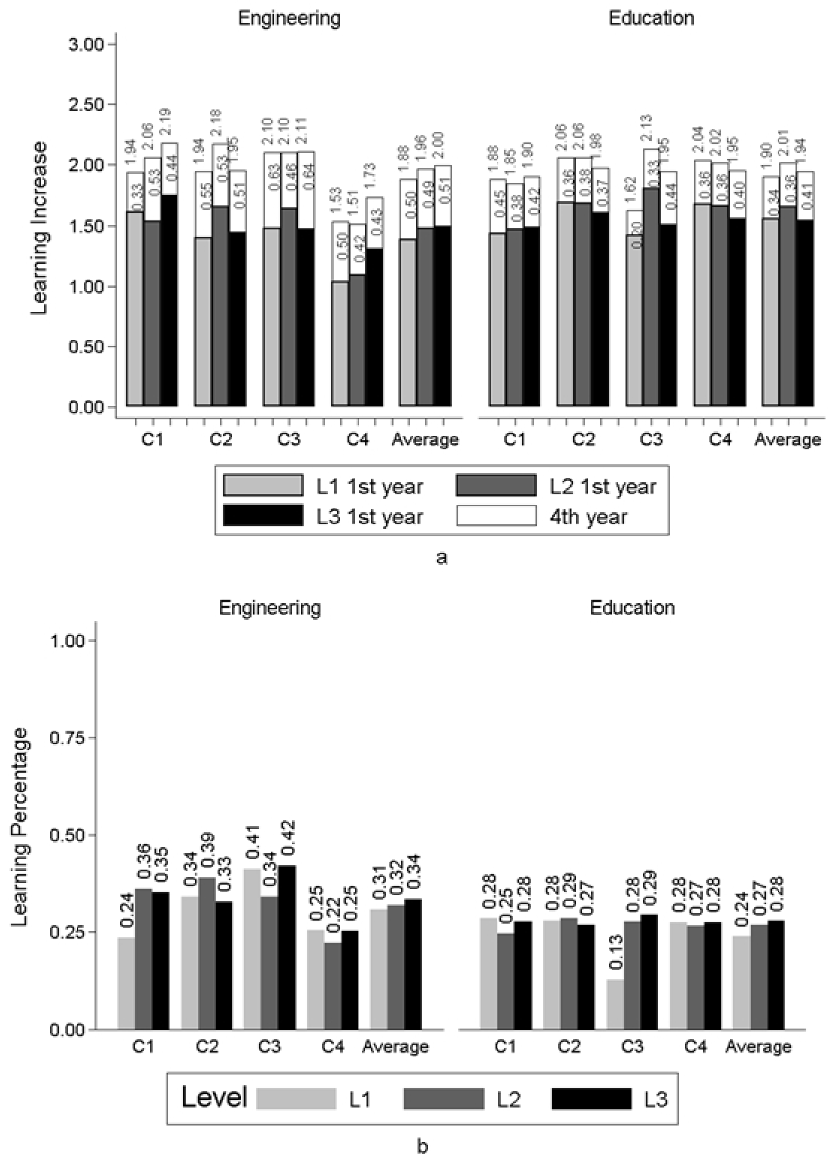

Figure 2. Learning declared by engineering and education students in each domain level for each competency and on average.

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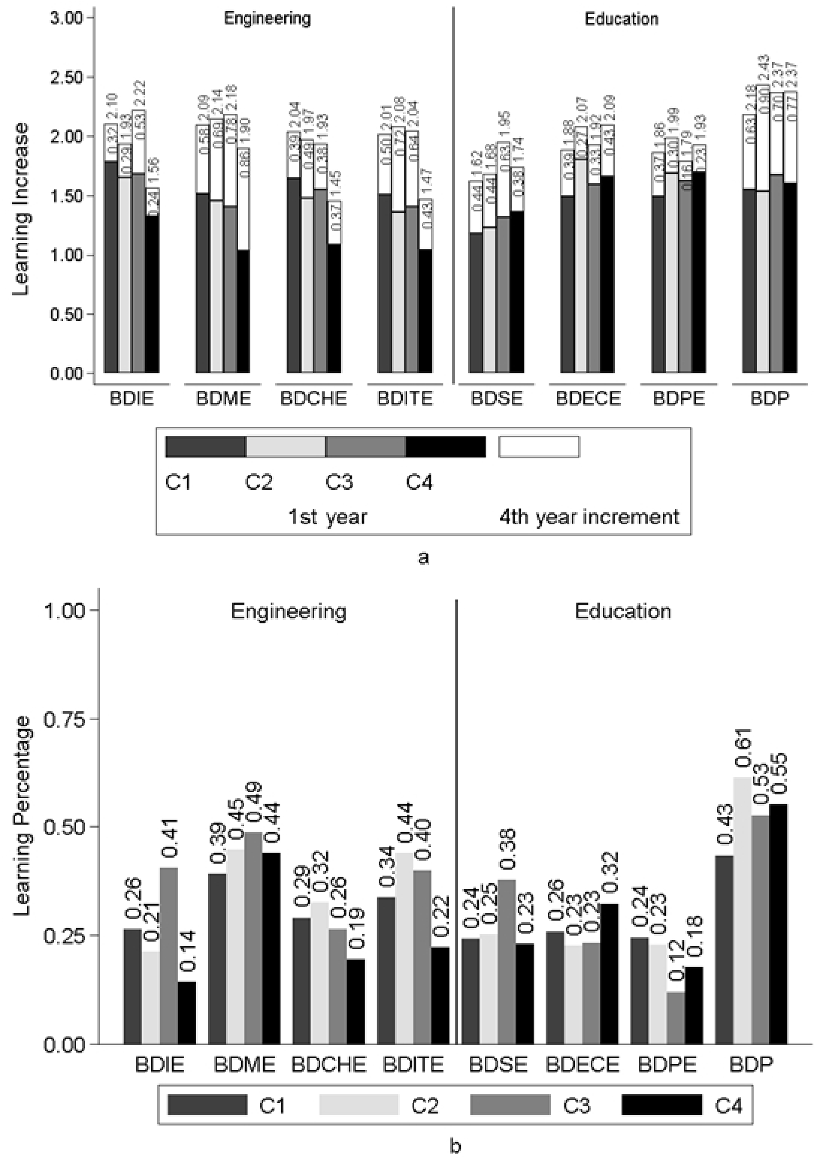

Learning declared by engineering and education students in each competency, broken down by degrees.

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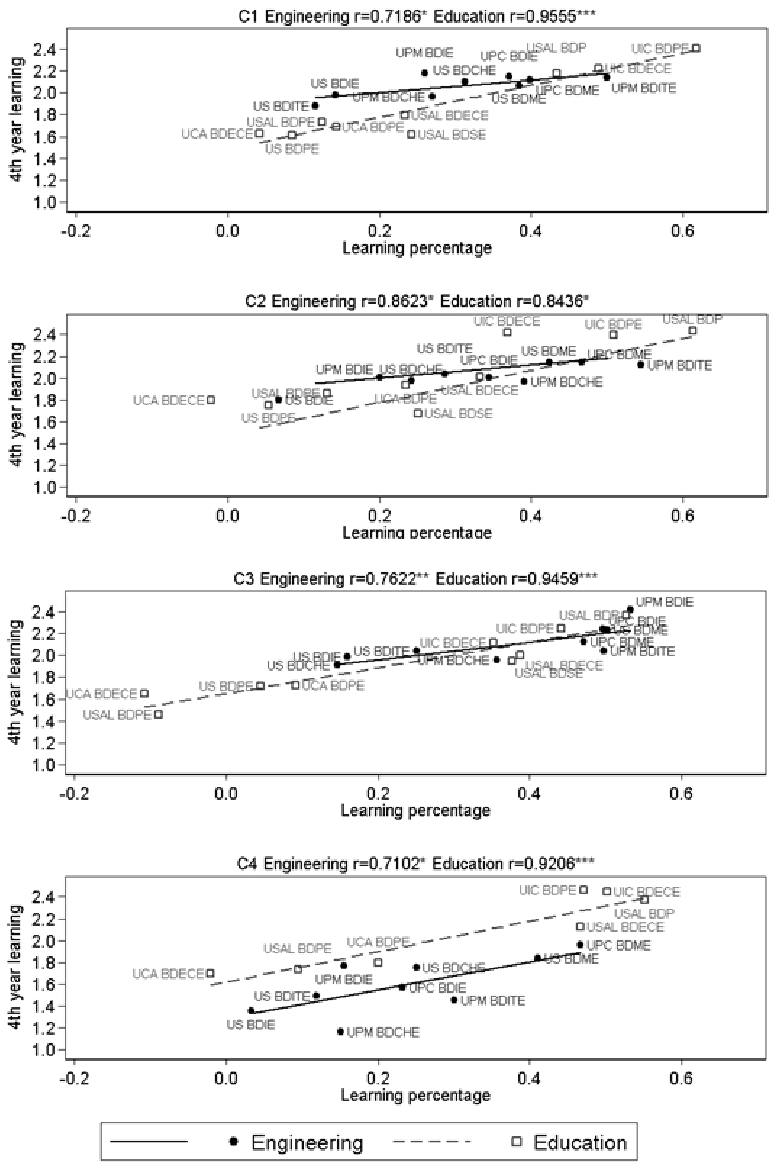

Figure 4. Correlation between the learning percentage and the learning declared by the fourth-year students.

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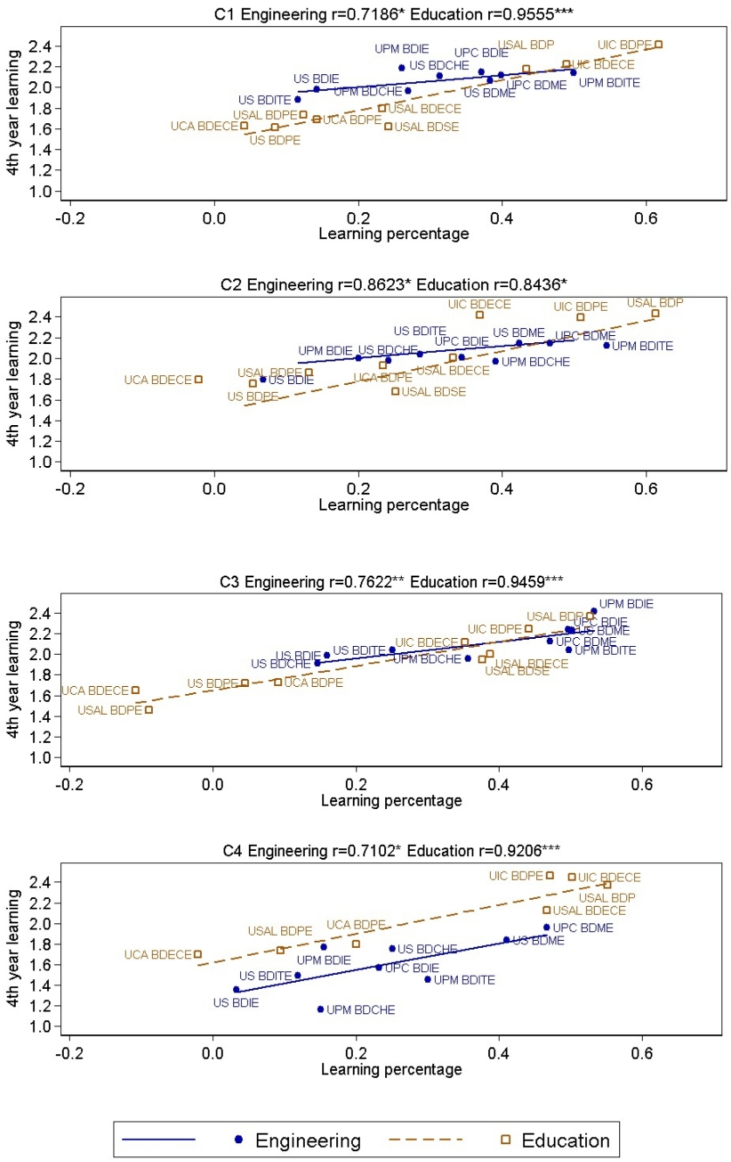

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