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Article

Analyzing Sustainability Awareness and Professional Ethics of Civil Engineering Bachelor's Degree Students

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Abstract: Teaching sustainability and ethics to engineering students is a challenging but necessary task that has been increasingly investigated during the last few years. In this research, a systematic method to identify the level of awareness in students about sustainability and ethics is developed. Here, it is applied to students studying the Civil Engineering bachelor's degree at the School of Civil Engineering of *Universitat Politècnica de València* (UPV), though this method is potentially applicable to equivalent ABET and EUR-ACE accredited bachelor's degrees. A survey was performed, and data was analyzed using Analytical hierarchical process technique; this technique determines the relative importance of each criterion, as well as the consistency of the emitted judgements, in an objective manner. These results allowed to discover that students do not have a robust opinion related to sustainability and ethics, except those students with previous experience in the construction sector. Environmental and social dimensions of sustainability and ethics were identified as the main focuses to emphasize in the civil engineering curriculum. Finally, actions to boot these principles are also proposed; potential courses where sustainability and ethics concepts could be explicitly included were selected and the inclusion of an environmental budget in the bachelor thesis was recommended, among others suggestions.

Keywords: education; sustainability; professional ethics; civil engineering; sustainable development goals; professional skills

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1. Introduction

Social concerns about sustainability have arisen since sustainable development was first defined by the Brundtland Commission [1]. In 2015, the United Nations approved the Agenda 2030 for Sustainable Development [2], in which a roadmap for sustainable development was proposed based on five pillars: planet, people, prosperity, peace and partnership. In this Agenda, 17 Sustainable Development Goals (SDGs) were defined, and industry and infrastructure were highlighted as key factors for achieving sustainable development in the 9th SDG.

Sustainability is particularly relevant in the construction sector due to its direct impact on its three dimensions: economy, environment, and society [3]. Investments in infrastructure promote the economic development of regions and facilitate access to services, such as public transport or drinking water. In this manner, the construction sector is directly related to the achievement not only of the 9th SDG, but also to the 6th SDG, Clean Water and Sanitation; the 11th SDG, Sustainable Cities and Communities; and the 12th SDG, Responsible Consumption and Production, among others. Moreover, construction managers have a wide variety of responsibilities, such as calculating the construction costs of the planned activities or preserving the wellbeing of their workers; these responsibilities are directly related to the achievement of the 8th SDG, Decent Work and Economic Growth.

On the other hand, great environmental stresses are derived from the construction sector: 30% of global energy consumption, 40% of extraction of raw materials and 30% of greenhouse gas emissions are associated with the construction sector [4]. Consequently, sustainability and climate change are arising as new design criteria for infrastructure [5–7]. Another relevant aspect in construction practitioners is professional ethics, where preserving or enhancing prestige and professional image may conflict with some of the sustainability aspects. Therefore, internalizing sustainability criteria and being aware of the scope in the consequences of decisions is critical in the civil engineering profession [8,9].

With all the above, major associations related to engineering education have become sensitive to the importance of including ethics and sustainability into engineering education in the last few years as today's students are tomorrow's professionals. The American Society of Engineering Educators (ASEE) stated that "engineering graduates must be prepared by their education to use sustainable engineering techniques in the practice of their profession and to take leadership roles in facilitating sustainable development in their communities" [10]. The American Society of Civil Engineers (ASCE) has taken a step forward by supporting the United Nations SDGs and highlighting the social dimension of the civil engineering profession when establishing that "As stewards of the nation's infrastructure, civil engineers must lead and advocate for sustainable design, programs, and development. This will require civil engineers to work collaboratively with a diverse group of stakeholders and foster strong relationships in our communities." [11]. In 2007, ASCE also published "The Vision of Civil Engineering in 2025" [12] based on the Future of Civil Engineering conference held in June 2006. In this text, the global aspirations for the future of civil engineers were summarized by stating that "civil engineers serve competently, collaboratively, and ethically as master planners, designers, constructors, and operators of society's economic and social engine—the built environment; stewards of the natural environment and its resources; innovators and integrators of ideas and technology across the public, private, and academic sectors; managers of risk and uncertainty caused by natural events, accidents, and other threats; and leaders in discussions and decisions shaping public environmental and infrastructure policy".

Given international concern over the significant role of sustainability and ethics in the civil engineering profession, civil engineering schools are starting to worry about the level of awareness of their students. El-Zein et al. [13] evaluated sustainability and ethical issues within the context of civil engineering education at the University of Sydney. The authors concluded that social sustainability was the most difficult concept to effectively include in the syllabus. Moreover, they recommended incorporating sustainability and ethics in the same course as, although they overlap, sustainability and ethics do not coincide. Understanding ethical principles is crucial for students and future professionals to be able to advocate for and attain sustainable development; this relationship between sustainability and ethics has also been stated in other studies [14–16]. Aginako and Guraya [17] assessed students' perceptions about sustainability in three different engineering degrees in the Basque Country (Spain) and a low level of insertion of sustainability in their curricula was found. Education for sustainable development and ethics directly impacts students' outcomes in terms of their awareness of such topics [18]. Thus, further efforts are required to determine the level of awareness of students and introduce efficient measures to improve the inclusion of these concepts in the curriculum.

In Gómez-Martín et al. [19], SDGs were introduced in the civil engineering bachelor's degree program curriculum of *Universitat Politècnica de València* (UPV) from the perspective of the whole degree; neither general concepts of sustainability nor ethics were considered in such work. Once the broad lines for the introduction of the SDGs are defined from the whole degree perspective, actions need to be taken at a lower scale. To implement efficient measures in each year of a civil engineering bachelor's degree, diagnosis needs to firstly be performed at a yearly scale. Hotspots can then be identified in each of the four years of this bachelor's degree. Afterwards, actions need to be taken at both degree and course scale based on the identified hotspots. The aim of this study is to develop a new methodology to systematically assess the level of awareness on sustainability and professional ethics at a course scale, based on the use of a survey together with Analytical hierarchical process (AHP) technique. The following research questions are aimed to be answered by this research:

A. Are the students' opinions about sustainability and ethics robust and well-built?
B. Which is civil engineering students' level of awareness on the different sustainability dimensions and ethics?
C. Which actions can be taken from a bachelor's degree perspective to cover the identified flaws?
D. Which actions can be taken from a course perspective to cover the identified flaws?

The aforementioned methodology is applied to third-year students studying for a civil engineering bachelor's degree at UPV within the framework of the course "Risk Prevention and Work Organization", as shown in Section 2. In Section 3, diagnosis and hotspot identification is conducted based on the survey results. In Section 4, actions to boost sustainability and ethics are proposed. In Section 5, both the identified results and proposed actions are discussed. In Section 6, conclusions are drawn.

Finally, it should be noted that this case study could easily be extended to other engineering degrees as: (1) safety and risk prevention are common topics within all engineering bachelor's degrees [20–22]; and (2) this degree program is accredited by both American (ABET) and European (EUR-ACE) agencies, meaning that it can be homologated with those offered by other universities with the same accreditation.

2. Materials and Methods

Different methodologies could be applied to analyze academic programs, such as interviews with students, academic stuff or other actors involved in the curriculum [23], as well as in-depth analysis of the curriculum [24]. Navarro et al. [25] suggested using the consistency value calculated with the AHP technique [26] to assess the critical thinking of master's degree students. In this research, a survey was first used to collect data from third-year students of the civil engineering bachelor's degree at UPV, as recommended by Cruz et al. [27]. Afterwards, the AHP technique was applied, similarly to Navarro et al. [25]. However, the present study considered not only the consistency of the emitted judgements but also the relative importance given to each sustainability dimension and professional ethics. In addition, the method given in Aguarón et al. [28] was applied to better estimate the consistency of the emitted judgements.

In this section, first the basis of AHP technique are introduced to show the criteria required to build the survey. After that, survey is described and, finally, the analysis of the survey results using AHP technique are detailed.

2.1. Basis of Analytical Hierarchical Process Technique

Sustainability and professional ethics are complex problems which involve a high number of criteria and may lead to challenging decisions. When engineers face a decision, they usually need to choose between different alternatives while keeping in mind the economic, environmental, and social consequences of their decision, as well as their ethical obligations. Therefore, it is feasible to address the assessment of sustainability and professional ethics as a decision-making problem.

Analytical hierarchical process (AHP) technique [26] is a multi-criteria decision-making method that is widely applied to assist in the decision-making process of complex problems where several criteria are considered. This methodology determines the relative importance of each criterion and the consistency of the emitted judgements in an objective manner. Consistency measures in which degree each emitted judgment matches the others; incongruities are penalized. Therefore, if this technique is applied to the judgements of students related to sustainability and ethics, it potentially allows to identify those aspects which are underrated and if students' opinions are robustly built and are, thus, consistent.

To apply the AHP technique, the pairwise comparison of the selected criteria needs was first performed; the decision maker needs to indicate the importance of each criterion when compared to the others within the framework of the decision-making problem. In this manner, a complex problem with a high number of criteria is decomposed in simpler problems, which are easier to solve by the decision maker. The mentioned pairwise comparison is performed according to the extended fundamental scale defined by Saaty [26]. This scale consists of 18 values; each semantic value is matched with a manageable numerical value, as shown in Table 1.

Table 1. Extended fundamental scale by Saaty [26].

Semantic Value	Numerical Intensity of Importance
Criterion *i* is as important as criterion *j*	1
Criterion *i* is slightly more important than criterion *j*	3
Criterion *i* is more important than criterion *j*	5
Criterion *i* is much more important than criterion *j*	7
Criterion *i* is extremely more important than criterion j	9
Intermediate values when further discretization is required	2, 4, 6, 8
Values used when Criterion *i* is less important than criterion *j*	Reciprocal

Based on the extended fundamental scale by Saaty [26], the decision matrix is obtained. This square matrix A_{nxn} is built so that each element a_{ij} corresponds to the numerical value which represents the judgement emitted by the decision maker when comparing criteria *i* with *j*. This matrix is reciprocal; thus, if a_{ij} = x, then a_{ji} = 1/x. The relative importance of each criterion can be calculated from the A_{nxn} as the values of the eigenvector corresponding to the largest eigenvalue (λ_{max}).

2.2. Survey Description

As previously mentioned, a survey was performed to study third-year students of the civil engineering bachelor's degree at UPV within the subject "Risk Prevention and Work Organization" during the first weeks of the course in September (first semester). This survey was divided in two sections: (1) basic data; and (2) data related to sustainability awareness and ethics. In the first section, participants' professional experience in the construction sector was requested.

In this study, the ASCE Body of Knowledge (BOK2) [29] was used as a framework to facilitate the contextualization of sustainability in the civil engineering problems. The Book states that upon graduation with a bachelor's degree, students should be able to "apply the principles of sustainability to the design of traditional and emergent engineering systems. Additional prelicensure experience should enable a civil engineer to analyze systems of engineered works, whether traditional or emergent, for sustainable performance". Moreover, ABET learning outcomes specify that engineering graduates should possess the "ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts". Thus, the second part of the survey was conducted to assess the sustainability awareness and ethics of the students within the construction work environment. To this end, a general practical case was proposed to the students [30]: they were construction managers and, thus, responsible for the execution phase and results of the construction of the infrastructure involved. According to this situation, the students were asked to evaluate the degree of importance of different aspects related to the decisions taken during the construction phase of the infrastructure. This was carried out by means of a pairwise comparison of the different aspects, as mentioned in Section 2.1. Since the capability of the human mind to emit accurate judgements decreases as the number of criteria increases [31], the sustainability and ethics problem was synthesized in the 6 aspects presented in Table 2.

Table 2. Sustainability and ethics aspects analyzed in the survey.

Aspect	Directly Related to	Statement in the Survey
Economic benefit	Economic sustainability	Improved economic result of the execution of the infrastructure
Risk prevention	Social sustainability	Improved risk prevention measures for the workers at the construction site
Environmental risk	Environmental sustainability	Maximum reduction in the environmental risk
Professional image	Professional ethics	Improved professional image towards the boss
Workers' wellbeing	Social sustainability	To promote the emotional wellbeing of the workers in the construction site (prevention of anxiety, depression)
Execution deadlines	Professional ethics; social sustainability	To meet the execution deadline at any cost

Economic benefit is the first aspect to be considered by the students because of its importance in the economic dimension of sustainability. Thus, economic benefit should be pursued in the construction of infrastructures to ensure the sustained and balanced growth of the economic fabric of societies according to the 8th SDG. Risk prevention and workers' wellbeing are also aspects to be considered by the students; they are directly related to social sustainability in the sense of guaranteeing decent work for all as set out in the 8th SDG. Risk prevention and workers' wellbeing are sensitive issues in the construction industry because industrialized societies demand a reduction in the accident rate to zero; however, such aspects are often in conflict with the productivity criteria. Environmental risk is an aspect to be considered by the students as the construction of infrastructure causes great stresses on the environment that must be limited and compensated to ensure the achievement of 11th (sustainable cities and communities) and 12th SDGs (responsible consumption and production). Execution deadlines is the last aspect to be considered as professional responsibility and ethics should lead practitioners to do their best to prevent delays: the outputs of civil engineering profession, such as infrastructure, are common assets; thus, delaying their commission directly impacts on society.

Ethics encompasses all judgements concerning human conduct [14]; therefore, the broad spectrum of moral values has been downscaled to a small group of behaviors that related to the confrontation of the personal professional image with social considerations. That would allow the evaluation of "what should be done" in the perspective of the students through a dialectic interaction between inner reflection and exterior judgement [32]. For instance, investing in better risk prevention measures for the workers may lead to dissatisfaction from their supervisors due to the decreased production yields, increased costs, and compromised deadlines.

2.3. Data Analysis

The survey was answered by 29 students; 18 were male and 11 were female. For those 29 students, 4 students reported professional experience in the construction sector. Once the survey was answered, its results were translated into 29 decision matrixes, as described in Section 2.1. Firstly, Aguarón et al.'s [28] method was applied on the matrixes and the consistency index was calculated. Afterwards, the AHP technique described in Section 2.1 was used to obtain the weights associated with each analyzed aspect (see Table 2).

Aguarón et al. [28] developed a methodology to maximize the consistency of decision matrixes by conducting small variations in the original emitted judgments within the limits of the uncertainty of those judgments. This methodology is supported by studies such as that conducted by Zadeh [31], who stated that the capability of the human mind to emit precise judgements decreases as the complexity of the problem increases (e.g., higher abstraction of the concepts or higher number of criteria). In addition, the scale used to characterize the importance of each aspect was qualitative; thus, the limits of the scores were not objectively defined. With all the above, the decision matrix presented a certain degree of uncertainty which hindered the consistency and weights calculation; this issue was overcome by means of using Aguarón et al.'s [28] methodology. The Consistency index (*GCI*) based on Aguarón et al. [28] is calculated as

$$GCI = \frac{2}{(n-1)(n-2)} \sum_{i<j} log^2 e_{ij} \tag{1}$$

where $e_{ij} = a_{ij}w_j/w_i$, being a_{ij} the elements of the decision matrix (numerical value which represents the judgement emitted by the decision maker when comparing criteria i with j) and w_i the weights obtained from Saaty [26] methodology.

As previously mentioned, *GCI* and the weights associated with each factor of the final matrixes were calculated according to the methodologies of Aguarón et al. [28] and Saaty [26], respectively.

3. Results

In previous sections, the survey used to characterize the level of awareness on sustainability and ethics among third-year students of civil engineering bachelor's degree was described, as well as the methodology for its analysis. Here, the results of this survey are presented and discussed.

3.1. Consistency Results

As shown in Section 2.1, consistency was used in this study to assess critical thinking of the students; robust and well-built opinions lead to consistent answers. The Consistency index, *GCI*, was calculated here using Equation (1); according to Aguarón et al. [28], *GCI* < 0.37 indicates that an answer is consistent. Figure 1 presents the values of consistency obtained for the 29 surveys, as well as the average *GCI* and the limit *GCI* = 0.37 [28].

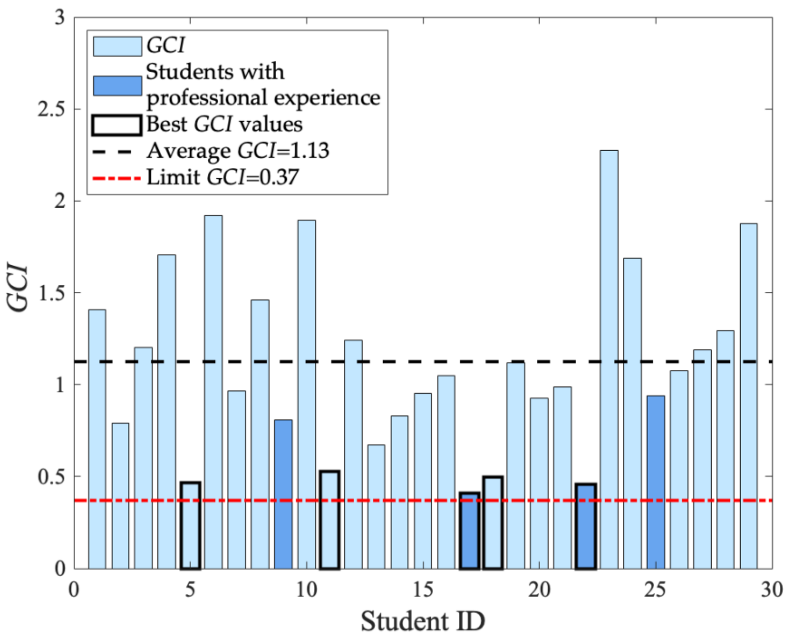

Figure 1. Consistency results of the survey performed to the students.

As shown in Figure 1, the consistency of the students' surveys was far from the limit in most cases; only 5 surveys presented reasonable *GCI* values (student #5, #11, #17, #18 and #22, highlighted in black in Figure 1). Moreover, a great variability in *GCI* for the 29 students was observed (coefficient of variation, CV = 44%). Similar results were reported in Navarro et al. [25] when analyzing the consistency in the judgements of master's degree students within the civil engineering and architecture sectors.

Significant differences were found between those students with and without experience in the construction sector, according to Mood [33] test (significance level α = 5%).

Students with previous experience in the construction sector (students #9, #17, #22 and #25 highlighted in darker blue in Figure 1) were more consistent (average *GCI* = 0.65) when compared to those without experience (average *GCI* = 1.20).

3.2. Hotspot Analysis

After assessing the robustness of the judgements in the survey, a hotspot analysis regarding the judgements of the students is performed in this section. This analysis assesses both the consistency in the judgements and the emitted opinions. For example, a student may have undesired opinions, such as that environmental sustainability is not relevant. These opinions should be identified, and academic actions should be taken to exclude them. Therefore, the weights assigned to each analyzed aspect are studied here so the aspects to improve and emphasize are identified.

It should be noted that decision matrixes need to be consistent to obtain fully reliable weights using the AHP technique. However, since the goal of this study is not to solve a decision-making problem but to discover what aspects students think are more important, weights obtained from the AHP technique can be used. Table 3 presents a summary of the statistics of the weights associated with each studied aspect; the distribution of these weights is shown in Figure 2 with a box-and-whisker plot [34]. No significant differences were found in the weights based on professional experience, according to Kruskal–Wallis [35] test (significance level α = 5%); the weights are not shown separately by professional experience in Table 3.

Table 3. Summary of the statistics of the weights obtained from the survey.

	Economic Benefit	Risk Prevention	Environmental Risk	Professional Image	Workers' Wellbeing	Execution Deadlines
Mean weight	0.21	0.15	0.17	0.18	0.20	0.09
CV (%)	28%	38%	39%	35%	29%	29%
Max. weight	0.34	0.31	0.35	0.31	0.34	0.17
Min. weight	0.11	0.07	0.05	0.06	0.11	0.03

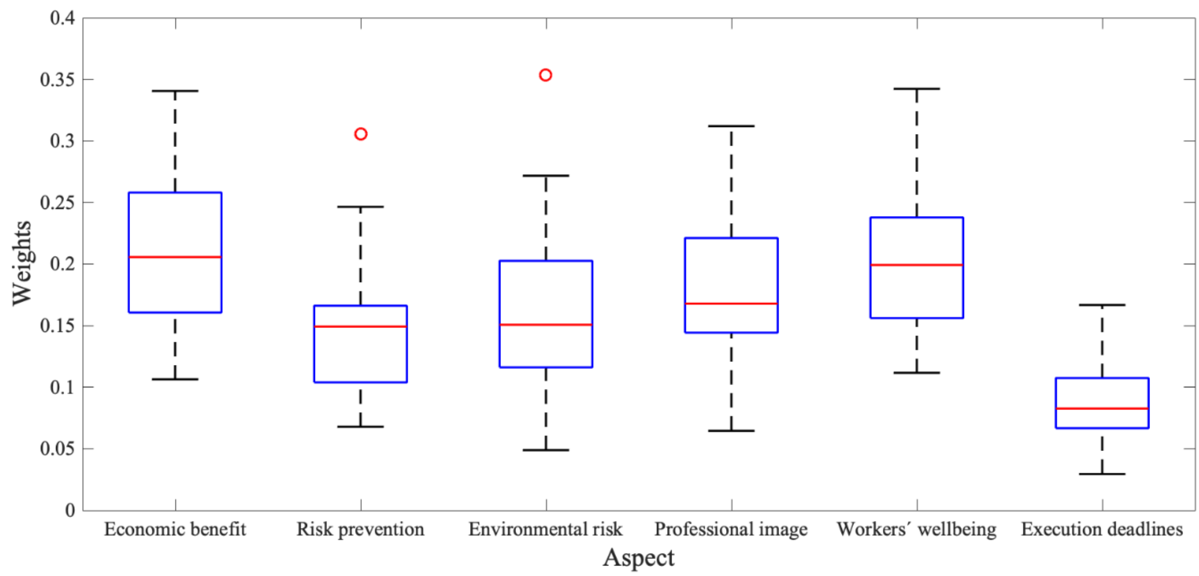

Figure 2. Box-and-whisker plot of the weights derived for each analyzed aspect.

The highest weight and lowest variability corresponded to economic benefit, while the lowest weight was obtained by execution deadlines. Risk prevention obtained the second-lowest weight with a high variability, while environmental risk was the aspect with the highest variability; this finding indicates that some surveys presented very low weights (10% of the surveys with $w_3 < 0.10$). Workers' wellbeing rated as the second-highest aspect and professional image presented the third-highest weight. These results are further discussed in the following sections.

4. Actions to Boost Sustainability and Ethics

In the previous sections, diagnosis of the third-year civil engineering bachelor's degree students was performed. Ideally, an equilibrium between the weights of the three dimensions of sustainability and ethics should exist and professional image should be the weight with the lowest value due to the way it was defined in the survey. However, risk prevention, environmental risk and execution deadlines were underrated, while professional image received a high score from students in the surveys. Therefore, actions need to be implemented to emphasize the significance of social and environmental sustainability and ethics during the civil engineering bachelor's degree syllabus.

Potential actions that incorporate new learning outcomes to the professional profile and academic program of a bachelor's degree can be proposed covering three levels, according to Gómez-Martín et al. [19]:

1. The first level consists of incorporating the new content in a transversal way using transversal and compulsory training activities, such as conferences or MOOC online courses. In this manner, students can understand the extent of the new learning outcomes.
2. The second level includes changes in the courses to introduce the new contents as direct learning outcomes. Based on the diagnosis performed in Section 3, activities can be proposed during the different courses to fill the identified gaps in the civil engineering program.
3. The third level proposes changes in the curriculum that involve a deep modification of the program and require a new validation by the national quality agency. Consequently, these changes are not easy to implement since they also require the renewal of the accreditations of the bachelor's degree.

In this study, actions to boost sustainability and ethics within the first and second levels are proposed since they are within the scope of the teaching staff of the course. Actions in the third level should be directly addressed by the Governing Board of the School of Civil Engineering.

4.1. Actions in Civil Engineering Bachelor's Degree

The consistency results presented in Section 3.1 indicated that most civil engineering students reach their third year without forming a robust opinion on the topics of sustainability and ethics. This is a worrying result; however, it cannot be considered anomalous since students in the last course of most bachelor's degrees in Spain do not achieve significant improvement in their sustainability competencies [36]. Therefore, further efforts and actions need to be implemented to improve the students' awareness and knowledge in these topics so they can properly build their own judgements.

Higher consistency was found in the surveys completed by students with professional experience. Thus, promoting and easing the process of accessing an internship during the early stages of the bachelor's degree may be an effective action to improve the awareness of students in sustainability and professional ethics. That didactic strategy is proven to promote competencies in sustainability and engage students in social action with a focus on social justice [37]. It should be noted that only around 49% of students take an internship during their civil engineering bachelor's degree at UPV, according to the data of the 2019–2020 academic year. This may be due to the difficulties in finding companies interested in recruiting students in the first year of their bachelor's degree and the difficulties in the compatibility of schedules. Therefore, establishing agreements with companies and increasing schedule flexibility may improve the percentage of students who access to internships. During the first two years of the bachelor's degree, most students lacked the technical background to successfully complete an internship in a consultancy firm or construction company. However, internships focused on supervision and bureaucratic procedures which do not require that thorough technical knowledge are proposed here, such as in the Water Boards or the Spanish Association of Civil Engineers (CICCP). For instance, in CICCP, students could be involved in the quality certification process for projects where, between others, it is ensured that the legislation regarding health and safety and environmental impact assessment are taken into account. In this manner, students would see the importance of these topics in daily practice, rather than as a single course in the civil engineering curriculum. An alternative to the above proposal is to carry out technical visits to construction sites; however, awareness of ethical and sustainability factors will necessarily be more limited since such visits are usually of short duration. Technical visits are performed very rarely during the bachelor's degree; therefore, it is identified as an action with room for improvement.

The second-lowest weight was found for the aspect of risk prevention. This is because the students completed the "Risk Prevention and Work Organization" survey in the very first sessions of the course; thus, they had not taken any course related to this topic. Thus, this result emphasizes the importance of this course in the civil engineering program curriculum for the knowledge of risk prevention measures and awareness of the related social sustainability concepts. However, since the safety of workers on construction sites is critical, further efforts should be undertaken to make students aware of its relevance. Thus, it is proposed to include short lectures focused on risk prevention in previous and subsequent courses. Based on the civil engineering curriculum given in Gómez-Martín et al. [19], legislation regarding risk prevention may be addressed in the course titled "Economics, Legislation and Business Management" (run in the first semester of the first year), while the drafting of the safety and health documents of a project may be studied in the course titled "Projects" (run in the second semester of third year).

A high variability in the responses regarding the importance of environmental sustainability was also observed, although the students had already taken courses such as "Science and environmental impact" (first semester of the second year) during the previous academic year. Environmental sustainability may be potentially included in common courses related to interventions or impacts to the environment, such as "Geology applied to civil works" (run in the second semester of the second year), "Construction materials and their application to CE" (run in the second semester of the second year) or "Construction Procedures (I)" and "Construction Procedures (II)" (run in the first and second semesters of the second year, respectively). Actions to promote environmental sustainability within the framework of "Risk Prevention and Works Organization" are proposed in the following section.

Ethics and professional responsibility were underrated by the students in the surveys. The course "Ethics in CE" (run in the second semester of the fourth year) is an optional course of the civil engineering bachelor's degree. A possible action to palliate the low awareness on ethics and professional responsibility of the students may be making this course mandatory in the civil engineering program curriculum. This course could adapt activities based on the PESTLE methodology to civil engineering, allowing case studies to be analyzed not only from economic, social, and environmental perspectives, but also from political and legal perspectives [38].

Finally, students must prepare a bachelor's degree thesis before ending their civil engineering bachelor's degree. This thesis is the most similar activity to the technical work that they will undertake as civil engineering practitioners; thus, it is the perfect opportunity to encourage a sustainable and ethical approach to the problem. Two actions are proposed here: (1) to include an "environmental budget" in the bachelor's degree thesis; and (2) to promote the Development Cooperation Program.

The bachelor's degree thesis usually consists of designing infrastructure and providing its economic budget. To emphasize the environmental sustainability perspective, it is proposed to quantify both its economic cost and environmental effects in terms of equivalent CO_2 emissions. This quantification can be performed using free databases such as Tecniberia [39]. In addition, it is possible to translate this amount of equivalent

CO_2 emissions into an economic cost through Intercontinental Exchange [40], which provides a price per ton of emitted CO_2. In this manner, awareness of the importance of economic sustainability observed in students in Section 3.2 can be used to improve their environmental consciousness.

Through the Development Cooperation Program, students can develop their bachelor's degree thesis with a humanitarian and cooperative perspective regarding an underdevelopment country. This approach would contribute to the current growing trend of adopting a transdisciplinary and holistic approach for sustainability and ethics [41] as interdisciplinary approaches put future professionals in an improved position to address the challenges related to social, economic and environmental dimensions of sustainability [42]. Note that only one or two students per academic year request this program. Promoting sustainability using humanitarian engineering and international projects was previously recommended by Ngo and Chase [43].

4.2. Actions in the Course "Risk Prevention and Works Organization"

After proposing actions at the bachelor's degree scale, actions within the framework of the course "Risk Prevention and Works Organization" are addressed here. The first step when (re)designing a course is to define the learning objectives (LOs) that the student should achieve. Once those LOs are defined, actions and assessment plans can be designed to ensure the alignment between the three objectives. However, when dealing with LOs related to sustainability, there is no consensus in the literature on how to create such a definition [44]. Here, it is decided to include the sustainability concepts within the specific LOs of the course by incorporating the sustainability perspective in the problems addressed along the course to align both sustainability and engineering practices.

The course "Risk Prevention and Works Organization" is composed of two blocks: (1) risk prevention; and (2) works organization. In the first block, legal frameworks and preventive actions to take on a construction site are introduced. Therefore, the course is partly oriented to show the importance of risk prevention in construction works; it is expected that this will boost the awareness of students mainly in two factors: risk prevention and workers' wellbeing. Following recommendations by Strachan et al. [45] and Burden and Sprei [30], the use of practical exercises similar to real cases are used in this block. As an example, a representation of construction sites to install a pipe is given to the student. The student is then asked to identify the main shortcomings and risks at the construction site and propose actions to correct and improve the work conditions.

The second block of the course focuses on works organizations and budgeting. Once again, practical exercises were used to apply the theoretical concepts exposed in the lectures. As an example, the students had to create a budget for a small part of an infrastructure project: building a retaining wall. To boost environmental sustainability and professional responsibility (execution deadlines factor), changes were proposed to improve awareness on these two factors. Firstly, students could select the production means necessary for the works to be carried out within a given execution timeline and, thus, evaluate the impact on the final costs [44]. Secondly, the students could calculate the CO_2 emissions associated with the construction works as a kind of environmental budget, as described in Section 4.1. The students could then propose ideas to reduce such emissions and evaluate the changes derived in the economic benefit and execution deadline factors. Finally, the debate technique could be used to criticize from multiple perspectives the ideas proposed by the students as debate-based technique has proven to be an efficient tool to develop critical thinking skills and acquire knowledge in sustainability and ethics [46].

It Is also recommended that some of the practical exercises described above resemble a real case, preferably a real construction work that could be visited at the end of the course; this approach would mitigate the students' lack of professional experience.

5. Discussion

In Section 3, results on the students' opinions were presented, whereas in Section 4, actions to boost the identified weaknesses were proposed. Here, both the results and proposed actions are discussed and compared with the previous results in the literature.

Although an equilibrium between the three dimensions of sustainability and ethics was expected, the results in this study do not correspond to that ideal situation. We attribute an overrated awareness of the students on the economic factor to the fact that, in most cases in the construction sector, the economic factor arises as the main criterion to determine the final infrastructure to be built within the technically viable solutions. In fact, budgeting and optimization of construction planning based on costs are part of the civil engineering students' curricula.

Although both workers' wellbeing and risk prevention were related to social sustainability, workers' wellbeing rated as the second-highest aspect, while risk prevention was the second-lowest criterion. The high score in workers' wellbeing may have been caused by the life stage in which students are living, which is characterized by a high social interaction, which in turn leads to a good empathy and emotional intelligence. However, students lacked any knowledge or experience of undertaking risk prevention on construction sites, preventing them understanding the dangers faced by construction workers. This points out the need for more practical experience, as indicated in the previous section.

Professional image presented the third-highest weight after economic benefit and workers' wellbeing. A possible explanation to this result is the fact that third-year civil engineering students are starting their professional careers; thus, they need to demonstrate their skills to their supervisors to improve their professional projection. It also seems clear that the academic institutions must insist on transmitting the message that civil engineering is primarily a public service, in which future engineers will manage public funds to provide infrastructure to society with the aim of improving social and economic welfare with an environmental perspective.

Environmental risk presented the fourth-highest weight and the highest variability, meaning that some surveys presented very low weights. This may be because, from an ethical point of view, humans have not acted rationally when it comes to the environment. They see it as an element to be dominated rather than preserved, being moral naturalized and consecrated by tradition and maintained through time [14]. However, ethics is dynamic since it adapts to new social demands; Therefore, environmental sustainability needs to be further emphasized during the civil engineering bachelor's degree syllabus.

The aspect considered as the least important by students was execution deadlines, which received a significantly lower weight. Students (as well as society in general) have probably internalized a message that construction works are routinely delayed since delays in the construction phase are frequent due to extreme climatic conditions and uncertainties in the basic data during the design phase.

In summary, civil engineering bachelor's degree programs are failing to balance the importance of the different sustainability factors. Students from first civil engineering courses valued people-centric objectives (e.g., quality of human life), followed by planet-centric objectives (e.g., quality of the environment) and prosperity-centric objectives (e.g., economic growth) [47]. Moreover, the opinions of the students of the 3rd course were not consistent, highlighting the need to take further action. Actions to palliate these flaws were proposed in Section 4 at both degree and course scale. Here, those actions are discussed.

It was observed that internships, practical cases, and field visits should be encouraged to boost consistency in students' opinions related to sustainability and ethics. This is in line with existing studies in the literature [48,49]. According to Børsen et al. [9] and Byrne [8], if ethics teaching to students in science and engineering is brought closer to real life, students become more involved. Moreover, ethics needs active reflection and project work makes students build resources, lead group work, and make collective decisions to learn to conciliate different points of view. Internships can boost ethical decision making. When university students and professors establish relationships with entities and companies in the industry, they learn to manage different interests and perspectives, discover other values, and use new ways of reasoning [9,49]. External partners, as future employers, legitimize the importance of integrating ethics and sustainability in professional practice.

In this research, the integration of sustainability and ethics in the syllabus was proposed in two ways in line with existing research [49]. Firstly, through the integration of sustainable development topics across all relevant courses. Sustainability and ethics are found in any engineering practice and cannot be addressed without collective and professional reflections [9]. Such integration would avoid the trap of considering both concepts to be the responsibility of only a narrow segment of the profession [47], while keeping it integrated with the engineering practice. Secondly, specific courses such as "Ethics in CE" are proposed to become mandatory in this research.

Finally, strengths, weaknesses, opportunities, and threats of the proposed actions are identified (see Table 4). The strengths are those aspects of the academic organization that would favor the adoption of the proposed actions; the authors have considered the affinity of the studies held in the School of civil engineering to the concepts of sustainability and ethics, the identification of the Governing Board with these concepts, the relative ease of incorporating the proposed actions in the curriculum and the high degree of involvement of the instructors of the course titled "Risk Prevention and Works organization". Weaknesses are those aspects that make it difficult to adopt the proposed actions and areas that the organization should improve; the Governing Board may not agree with the specific measures proposed in this study, teaching staff of other subjects may be skeptical and immobile, and it may be difficult to find companies in the sector willing to host internship students during the early stages of their bachelor's degree. Opportunities and threats are external situations that may affect the organization. The opportunities identified are related to the predisposition of the teachers of the "Risk Prevention and Works organization" course, as well as the improvement in learning outcomes and students' motivation. The identified threats are linked to an increase in the workload of the students due to the academic staff practices and the companies which host trainees.

Table 4. SWOT of boosting sustainability and ethics in the Civil Engineering bachelor's degree.

Weaknesses	Threats
- The Governing Board of the School of Civil Engineering may find difficulties in coordinating the proposed actions with the existing academic program - Teaching staff presents some immobility - The degree of involvement of teaching staff along the bachelor's degree may be quite uneven - Private companies are not keen on hiring interns in the first courses of civil engineering bachelor's degree	- Students may perceive internships as an excessive workload to balance with their studies - Students may perceive the proposed actions (e.g., new activities and concepts in the courses) as an increase in their study load - Teaching staff may include the proposals without giving up other content, causing student overload - Private companies may require too much effort from the intern
Strengths	**Opportunities**
- The civil engineering context is very suitable for introducing sustainability and ethics concepts - The proposed actions do not imply deep changes in the curriculum - The instructors of the course known as "Risk Prevention and Works organization" are actively involved - The Governing Board of the School of Civil Engineering is concerned about sustainability - The UPV Center for Development Cooperation has been previously involved in activities to promote SDGs	- The instructors of the course "Risk Prevention and Works Organization" recognize the need to include sustainability and ethics through course-scale actions - The development of the proposed activities will improve the learning outcomes of students - The development of practical cases, field visits and internships will enhance students' motivation - The assessment at a yearly scale will improve the follow up of the students through the bachelor's degree

6. Summary and Conclusions

The concept of sustainable development has produced a shift in the vision of the construction industry's future. Sustainability improves the social wellbeing and the development of the countries while environmental assets are preserved and protected from climate change. Civil engineering practitioners have a key role in achieving such a sustainable future as infrastructure is directly related to the economic and social development of regions and the quality of life of the population. Moreover, the civil engineering profession involves great responsibilities and complex decision-making processes, in which ethics are essential. Consequently, universities must ensure that the civil engineering bachelor's degree program is aligned with sustainability-related values and ethics in the practice of the profession as they are responsible for the education of future professionals. Thus, in this study, a diagnosis was performed on third-year students of the civil engineering bachelor's degree program at UPV by means of a survey and the following research questions were addressed:

A. Are the students' opinions about sustainability and ethics robust and well-built?

The robustness of students' opinions was assessed by means of the Consistency index (*GCI*) as defined Aguarón et al. [28]. The provided responses were not consistent, thus indicating that students' opinions related to sustainability and ethics were not well-built.

B. What is civil engineering students' level of awareness on the different sustainability dimensions and ethics?

Ideally, an equilibrium between the three dimensions of sustainability and ethics would be observed in the students' opinions. However, the results were not in equilibrium. Consequently, environmental and social sustainability and ethics were identified as the main aspects to emphasize during the civil engineering program.

C. Which actions can be taken from a bachelor's degree perspective to cover the identified flaws?

Higher consistency was found for students with professional experience, so internships, practical cases and field visits should be encouraged. In addition, potential courses where the concepts of environmental and social sustainability and ethics could be explicitly included were identified. Moreover, it was proposed the course "Ethics in CE" become mandatory. Finally, the inclusion of an environmental budget in the bachelor's degree thesis was recommended.

D. Which actions can be taken from a course perspective to cover the identified flaws?

Within the two blocks of the course that covered "Risk Prevention and Works Organization", different practical exercises resembling real cases were proposed to compensate for the students' lack of professional experience. In those study cases, the students were asked to identify shortcomings and risks to proposed actions to improve workers' conditions, environmental impacts, costs, and execution times for the intervention. Their conclusions were proposed to be debated with peers to boost critical thinking and awareness. Finally, the calculations of the CO_2 emissions associated to construction works were included as a kind of environmental budget and practice for the bachelor's degree thesis.

Some barriers to those actions were identified since the degree of involvement of teaching staff and the Governing Board of the Civil Engineering School is uncertain. However, the Governing Board of the Civil Engineering School has previously participated in the promotion of SDGs, meaning that they are aware of the new needs regarding sustainability in the civil engineering profession. On the other hand, the risk of student overload due to the inclusion of the new concepts should be carefully analyzed.

In this study, the follow-up of the students along the different courses has been highlighted to ensure the attainment of the professional skills relevant for sustainability and ethics principles. Future work is required to implement the proposed actions and to track the evolution of the students through each year of the civil engineering bachelor's degree. In this case, quantitative techniques (surveys) would again be needed and complemented with qualitative techniques (i.e., interviews and focus groups) to determine the reasons behind the quantitative results.

Finally, the civil engineering bachelor's degree at UPV is accredited by both American (ABET) and European (EUR-ACE) agencies. This means that UPV curricula meet criteria common to other accredited universities in the world; thus, the conclusions drawn from this research could be extrapolated to other universities with the same accreditations. Future research should focus on developing comparative studies with other national and international centers to check the degree of agreement with the conclusions stated here.

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