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Education for Sustainable Development (ESD): An Example of Curricular Inclusion in Environmental Engineering in Colombia

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Abstract: This paper presents a case study whose central axis is the inclusion of the subject of education for sustainable development (ESD) in the undergraduate study plan of the environmental engineering degree at the Santo Tomas University, Colombia (USTA). This study is based on a diagnosis developed from a survey conducted among students from USTA and 43 professors from 13 universities that offer environmental engineering degrees throughout Colombia. The diagnosis showed some gaps in ESD knowledge and its applicability for both students and professors; in contrast, participants had a significant understanding of environmental education (EE). Therefore, a curriculum review was also carried out. Once the problem was identified, an ESD subject aligned with the purposes of sustainable development (SD) was proposed. Finally, the acceptance of the subject that ESD students had attended was evaluated compared to other students who had not participated this subject. This research seeks to provide a way to fill the knowledge gaps in environmental engineering among students. Relevant results include the identification of a gap in SD knowledge in environmental engineering professors. In addition, students were found to be more trained in EE than in SD. Nevertheless, the incorporation of ESD contributed to a better understanding of SD.

Keywords: curriculum; education for sustainable development; environmental education; environmental engineering

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1. Introduction

The current environmental problems have generated significant interest in different academic fields, including the educational area, in order to integrate environmental issues. Education constitutes a strategic training space in which scientific and philosophical knowledge is taught. Moreover, it promotes social and environmental changes by enabling individuals to fully understand the dynamics of society and their own role within it [1].

The teaching and learning strategies developed in the environment-related educational process have traditionally been structured through environmental education. Such strategies are based on a series of different theories transmitted through the teaching and learning process. All this responds to the needs of the society to train competent people with values, attitudes, and skills that seek to solve environmental problems [2]. EE has been developed from a flexible structure, i.e., it is adaptable to changes according to the progress of humanity [3].

This process is reflected in higher education institutions (HEI), which can be considered as one of the main instruments of the educational system. They contribute to the development of strategies focused on the protection of the environment, which in turn provides a platform for sustainable development (SD) [4]. In addition, HEIs have a high degree of responsibility in training people to be prepared and have the tools to fulfill their roles in a globalized society [5,6].

The sustainable development goals (SDGs) are a benchmark and a milestone in the SD discussion [7]. This strategy is expected to lead companies, communities, and especially governments to make progress towards achieving SD [8]. Through this integrative approach, the globalized economy and the current prevailing consumption model can transform into a responsible system in tune with the environment [9]. Education plays an essential role in the promotion and instruction of SD, and especially of the SDGs. In this sense, education for sustainable development (ESD) has been pointed out as the way forward [10].

From a holistic approach, ESD sets the basis for achieving the SDGs [11]. ESD in HEIs also responds to the needs in the labor market, whereby companies are increasingly interested in hiring SD-literate graduates [12]. Therefore, HEIs are called upon to lead and promote the transition towards sustainability through teaching, research, dissemination, and community participation [13–15].

In this sense, some HEIs are undergoing a rapid change, influenced by the new needs of society, which are mainly focused on environmental issues. For this reason, EE or ESD has been adapted and implemented in different academic programs. However, ESD has not been successfully applied in Latin America, specifically in Colombia, due to the lack of training and pedagogical strategies for learning and teaching ESD [16]. This educational ideology has gained prominence since the United Nations declared the Decade of ESD 2005–2014. Despite its greater acceptance in Europe and Asia, it remains unknown in places such as Latin America. This lack of awareness may be a result of the absence of clear policies that promote ESD in formal education in Latin America [17]. A recognizable characteristic of ESD is that it holistically addresses the three fundamental pillars of SD: society, environment, and economy [18,19]. Therefore, ESD seeks to transform people, their environment, and society. In order to create a significant impact in all levels of society and achieve the SDGs, these changes must be reflected in the thought process and actions of people [20–22]. Furthermore, ESD seeks to promote the three fundamental pillars of SD, i.e., it depends on economic growth [23]. In contrast to the ESD, the EE is characterized by being protectionist and seeking the generation of awareness. For this reason, it differs from consumerist economic models and economic growth [24,25].

HEIs have started to progressively include environmental engineering within the area of engineering. In some countries, this discipline is a branch of postgraduate studies [26–28], while in others, such as in Colombia, EE is a bachelor's degree. One of the aims of said degree is to find solutions that mutually benefit humans and the environment through the restoration and creation of ecosystems [29]. In this sense, engineering programs have to adopt ESD in order to promote the integration of SD into the technical and technological areas of each profession. Thus, environmental sustainability should be transversal to engineering education [30].

Professors are a crucial factor in the promotion of education and the achievement of environmental sustainability. The support provided by them and their research on ESD in HEIs is fundamental for teaching and learning [31]. Professors strive for social change through ESD by teaching students the principles of environmental sustainability in each professional field [32]. This approach ensures that ESD incorporates professors as essential actors in achieving the SDGs [33]. The restructuring of teaching is a major challenge, as it represents changes in disciplinary approaches to identify solutions to social, economic, and environmental problems from each discipline. This challenge highlights the need for new curricula; in turn, professors must be trained and prepared [31,34]. This research is divided into three parts, described below:

a. ESD knowledge of environmental engineering professors in Colombia

A survey completed by 43 higher education professors of environmental engineering from 13 Colombian universities confirmed a gap in the level of ESD knowledge. In the same way, it was found that professors are predominantly knowledgeable in EE.

b. *Creation of an ESD subject in environmental engineering at Santo Tomas University, Colombia*

A committee handles curricular matters within the academic and administrative structure of the USTA environmental engineering program. Observing the survey results of professors, students, and the curriculum review of the USTA environmental engineering program, a course with a syllabus focused exclusively on ESD was developed during 2019 and 2020. The proposed subject was taken by fourth year students during 2020. In addition, a survey was conducted among the students who participated in this course, which sought the acceptance of ESD and its importance for future careers.

c. *Knowledge of EE and ESD within Santo Tomas University*

A comparison was made between students who took the subject in ESD and those who did not, in order to assess the possible incorporation of ESD into environmental engineering and make it definitive and replicable.

With these three parts, an attempt was made to address the curriculum and its actors (students and professors) to identify the problems associated with the teaching of ESD and, in turn, promote what Chaves et al. (2017) call "transgressive learning". Transgressive learning is prevalent in Colombian society and can be culturally translated to the university classroom. It can be understood as a plurality of knowledge related to sustainability [35].

The research questions posed were the following: (1) What is the current state of the integration process of ESD in engineering education in Colombia? (2) How does the introduction of an ESD subject affect the application of SD knowledge in USTA environmental engineering students?

However, it is essential to mention that this is a case study, and there are similarities between the curricula of the universities that offer environmental engineering in Colombia. This research must be taken as a basis or an example only to properly plan a curricular evaluation within each university seeking the implementation of ESD.

In the following two sections, we will outline the context and background of EE and ESD in Colombia.

1.1. Brief Context of Environmental Education in Colombia

EE and ESD are educational models whose main objective is to preserve natural resources for current and future generations [36]. Furthermore, the EE and ESD action pillars are based on the role of the professors, research, social projection, and management strategies to achieve them [37]. In the academic context, we can find similar definitions and generalized acronyms, such as "environmental education for sustainable development" (EESD) and others [38,39]. In this sense, in many cases, there is an overlap between EE, ESD, or EESD specific ideas and objectives. Each model has defenders and detractors; Colombia is no exception, although it is clear that such a debate strengthens research motivation within academia [5,40,41].

EE is an important educational model. It has been in continuous evolution, which has enabled us to identify the impacts on natural resources. Furthermore, EE generates strategies for the mitigation and conservation of nature that incorporate biophysical, social, and political realities, creating the appropriate awareness for the rational management of natural resources [5]. At the 1987 Moscow International Congress, EE was defined as "*a permanent process in which people and communities become aware of their environment and learn the knowledge, values, skills, experience, and also the determination that allows them to act individually and collectively to solve present and future environmental problems*" [6].

In this sense, EE seeks to modify the relationships between nature and human beings, generating social change and empowerment to achieve more harmonious and just societies [42] and enable a personal and collective development that is fairer [43].

In Colombia, the "Environmental Education Policy" was developed to generate a navigation route that would bring together EE's principles, objectives, and actions. This document sought an educational process that fluidly links culture and environment, targeting both urban and rural populations [42]. In this policy, there is no allusion to ESD;

on the contrary, this document is disconnected from many of the realities of the country and academic researchers in the area [44]. Colombia's environmental education policy prioritizes basic primary and secondary education over higher education, meaning HEIs have the freedom to interpret their position regarding EE [45]. In some cases, EE initiatives in HEIs are deficient because they do not adopt an approach that is guided by the vision of sustainable socioeconomic development, which allows not only the conservation of resources, but also their expansion, guaranteeing the collective survival of the planet [46]. This characteristic is typical of the theoretical foundation of EE, although, in practice, it is clear that HEIs must provide their future professionals with theoretical, practical, and innovative tools aimed at improving the environment through any approach [1]. At this point, it is essential to clarify that although Colombia's environmental policy dates from 2002, this does not mean that there are no other laws that promote EE in this country, but rather that they are focused on basic education. This is mainly due to Article 69 of the Political Constitution of Colombia, which determines university autonomy. Even so, universities can voluntarily become part of the "Inter-Institutional Environmental Education Committees" (CIDEAS), joining the development processes articulated in projects and plans of communities and EE actors in their regions [44,45].

1.2. From EE to ESD

Considering that Colombia is a developing country, it is crucial to find the most effective way to educate the population on achieving SD. Today, the 17 SDGs are the most promoted tool to achieve SD [47]. The Colombian government has gradually designed frameworks to articulate the SDGs within their development plans. The SDGs aim to show a shared vision of the future to guide clear commitments to address pending challenges and design a path that balances economic, social, and environmental variables [47]. At all levels of higher education, the SD perspective helps individuals acquire knowledge and ethical values that enable participatory and responsible management of the environment at local, national, and international levels [48].

The responsibility of educating people on SD must be assumed by interdisciplinary and multidisciplinary teams within university educational institutions, highlighting the role of professors, who must commit to leading their students through good actions and knowledge regarding sustainability [11]. In this sense, ESD is recent and innovative, and its purpose is to promote a solid education that allows for greater awareness of the state of the planet. This approach aims to foster responsible attitudes and commitments, preparing people to make SD-oriented decisions, whereby social, economic, and environmental factors prevail [49]. It is essential to mention that in Colombia and some places in Latin America, ESD lacks recognition and application. Therefore, to achieve the SDGs, ESD must be inclusive, conscious, restorative, cooperative, critical, and linked to the environment in order to contribute to improving quality of life [50].

One of the characteristics of ESD is that it goes beyond the dissemination of knowledge and considers specific pedagogies and learning environments. Likewise, it is more participatory and involves clusters between different actors in society [51]. Therefore, it requires collaborative methods that motivate empowered individuals to change their behavior and promote skills such as critical thinking, collective decision-making, and the transformation of themselves and societies [52]. The objectives of ESD can be summarized as follows: (1) to understand the interdependence of all forms of life and the current and future impact of human actions on resources; (2) to become aware of the influence of economy, politics, culture, society, technology, and the environment on the development of SD; (3) to develop capacities, skills, attitudes, and positive values to achieve SD at the local, regional, national and international levels; (4) to show interest in proposals that help promote ESD [53]. We have sought to show the lack of promotion of ESD at various levels of society in Colombia, especially by the government and universities. We started with the fact that universities play an essential role in achieving the international sustainable development agenda (Agenda 2030). One of the goals set out in SDG 4 is to guarantee that students acquire knowledge and skills in SD [54]. On the other hand, the incorporation of a subject sought to find a practical way to respond to the need for environmental engineers to be increasingly trained in SD, and for them to be integrated into the process of compliance with the SDGs.

Therefore, this research focused on ESD without ignoring the importance of EE, highlighting the gap that Colombian universities have in exploring and experimenting with ESD. This emphasizes that, although it is a case study, it is based on a general survey of teachers where gaps in knowledge of ESD are evident, and that the data from this research can be used as input for research or similar curricular evaluations in Latin America, since the curricular characteristics of Colombia are shared in many Latin American countries [40,45,55,56]. One of the most used and studied ways to include ESD into curricula is to propose subjects that can be easily included in the study plan. On the other hand, some approaches seek a comprehensive and total transformation of the curriculum, which is more complex and laborious—for example, preparing all professors to successfully teach SD subjects. In both cases, it is necessary to carry out collaborative curricular evaluations, where all academic actors evaluate and formulate the changes [57–60].

2. Materials and Methods

This study was inspired by different factors, among which are those described by Desha et al. (2009): namely, the 3 phases needed to achieve the integration of ESD in engineering and to carry out a curricular renewal according to current needs. The first phase is called the 'ad hoc' phase by students and professors. Then, a different path was followed for the second phase to involve general knowledge regarding SD (in this case, the addition of a subject within ESD). Finally, the third phase involved the same process of adding subjects within ESD [55]. Therefore, although this study followed the actions taken by other researchers and it has the same common goal, it differs in the use of specific methods. The questions on the surveys were asked without asking for personal or contact information. Age was consulted only for statistical purposes in accordance with the legal conditions in force in Colombia and as established by the Universidad Santo Tomas in its committees, specifically approved by the Curriculum Committee of the Faculty of Environmental Engineering of the Universidad Santo Tomas in file 02 of 13 February 2019. In order to provide further dissemination and evaluation capacity in the appendices of this article, the questions asked to teachers and students can be found. The questions asked to professors differed from those of the students, with more technical language addressed to the professors.

Figure 1 provides a summary of the methodological process used in this study. It is important to note that some stages were only applied at Santo Tomas University.

2.1. Determination of Knowledge of ESD in Environmental Engineering in Colombia through Surveys to Professors

A survey was conducted on 43 professors from 13 Colombian universities. Of the 43 answers, 39 belonged to environmental engineering programs. The questions were phrased in positive form, and the horizontal Likert scale model was applied to the answers. Questions presented in this style are structured as a request for an answer, followed by a statement and a rating scale to answer the posed question [61]. The horizontal scale was chosen to avoid extreme response trends, which tend to occur more frequently in vertical-type options [62]. The scale varies from 1 to 4, whereby 1 is equivalent to "not at all" and 4 is equivalent to "completely", corresponding to a unipolar scale [63]. One question was asked regarding age, while the remaining 21 questions were related to the subject of study. Question one (Q1) was related to the respondent's job as an environmental engineering professor. Q2 established the degree of knowledge of EE, while Q13 referred to the curricular areas where EE or ESD should be more emphasized. The first questions assessed whether professors teach concepts, practices, or theories about EE, while the latter questions focused on the knowledge, theory, and application of ESD, as well as the professors' attitudes towards students. The questions asked to professors are shown in Appendix A. The questions were numbered and proposed in a fixed order to have a logical sequence and not alter the Cronbach alpha values.

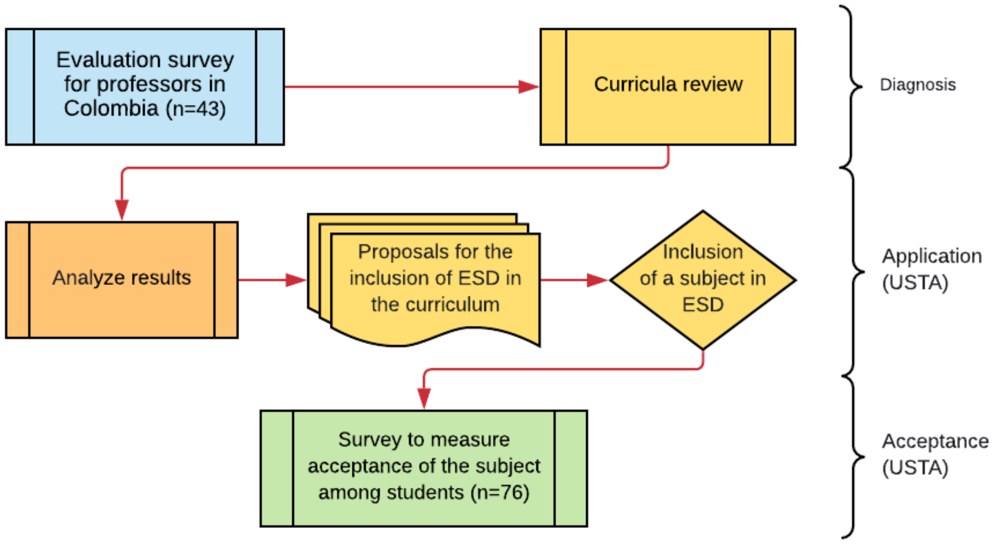

Figure 1. Methodological summary.

2.2. *Curriculum Review at Santo Tomas University (USTA)*

The curriculum of the environmental engineering degree program was reviewed. This program consists of 10 semesters or academic courses that are completed over five years. This review was carried out, in general terms, by identifying the knowledge areas that the academic program covers, in order to learn the basic concepts of environmental engineering. Subsequently, the theoretical, training, and methodological bases of these areas were determined, incorporating both theoretical and practical activities. Finally, we selected those courses whose theoretical foundations were most closely related to ESD and EE [64].

A curriculum review is a participatory process involving students, professors, and -administrative staff, among others. In this process, valuable information is obtained and analyzed to judge and make decisions regarding the curriculum's structure, operation, and administration. During the curriculum evaluation, the main objective is to determine which of the two educational models is immersed in the pedagogical processes of the courses offered by the academic program [65]. The review was carried out by the curricular committee of the Faculty of Environmental Engineering based on the documents and institutional guidelines of the USTA. The USTA's methodology implemented for the curricular evaluation can be seen in Figure 2. The objective of the environmental engineering undergraduate program is the comprehensive training of highly qualified professionals in engineering as it applies to the environment, instilling them with creative skills, scientific rigor, and high social sensitivity. Moreover, this program prepares students for the study and analysis of problems related to the environment, sustainability, and the relationship between individuals and nature. Ultimately, this aims to allow them to design and propose efficient solutions to the environmental problems faced by society.

The USTA environmental engineering program curriculum is summarized by knowledge area in Table 1.

An elective course focused on ESD was proposed to the curriculum committee. To this end, a group of professors determined to offer this subject in the 2018–2019 academic year. In addition, the total number of students who had to take this subject was assessed (i.e., they did not opt for another elective subject). The elective courses offered were ESD and Strategic Management. The syllabus consisted of a series of EE-oriented topics.

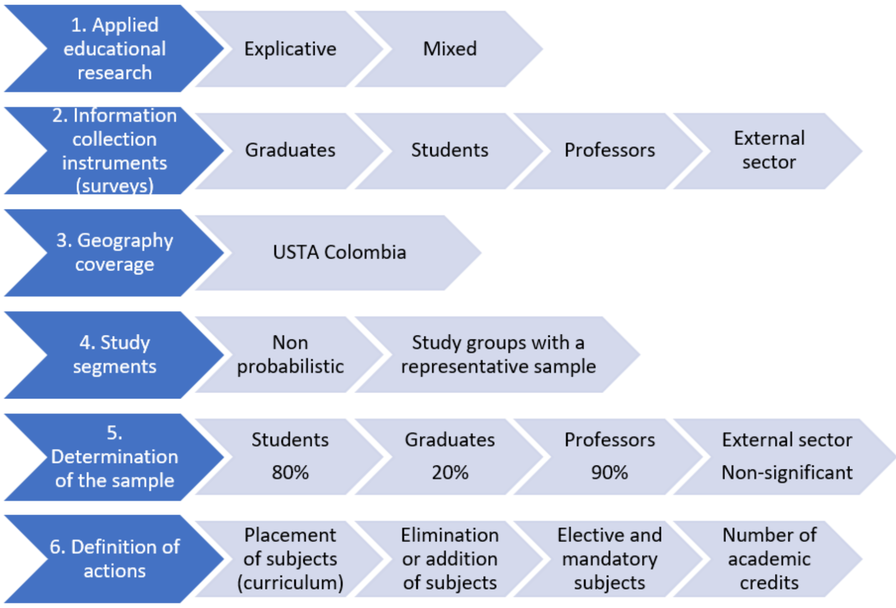

Figure 2. The USTA curricular evaluation model is applied to the environmental engineering undergraduate degree.

Table 1. Environmental engineering study plan by training area.

Training Area	Subjects
Basic Sciences	Differential calculus; Linear algebra; Integral calculus; Mechanical physics; Inorganic chemistry; Vector calculus; Physics of waves, fluids, and heat; Organic Chemistry; Differential equations and Programming logic.
Institutional Training	Institutional philosophy; Physical Culture; Anthropology; Epistemology; Theological culture; Political and ethical philosophy
Basic Sciences of Environmental Engineering	Biology; Ecology; Geology and Soil Sciences; Probabilities and statistics; Environmental microbiology; Fluid mechanics; Thermodynamics; Climatology; Hydraulic resources; Fundamentals of Economics and Management; Chemistry and Air Quality; Hydrology; Environmental Economics and Economic Engineering
Foreign language	English I; English II; English III; English IV; and English V
Applied Environmental Engineering	Introduction to Environmental Engineering; Environmental legislation; Topography and Cartography; Geographic information systems; Engineering Research; Field techniques; Drinking water treatment; Solid waste management; Environmental impact; Sewage treatment; Management of Environmental Processes; Environmental solutions; Environmental Modeling and Simulation; Environmental management systems; Formulation and evaluation of projects; Undergraduate seminar; Updated seminar and undergraduate option.
Elective Component	Elective I (Environmental Policy); Elective II (Land use planning); Elective III (appropriate technologies); Elective IV (Business management); Elective V (Education for sustainable development).

2.3. Measurement of Acceptance of ESD through a Student Survey

To determine the level of acceptance of ESD and EE, 70 of the 192 undergraduate students in environmental engineering at USTA were surveyed randomly. The survey was divided into three sections. The first section was based on determining students' knowledge of ESD. The second section aimed to identify the level of acceptance of EE, taking into account the developed concepts and practices. Finally, in the third section, a comparison between the two streams of EE and ESD was made, highlighting the actions, concepts, and characteristics to be recognized and differentiated by the students.

As mentioned above, the response options were based on the Likert scale, from (1) the highest degree of disagreement to (4) the highest degree of approval. The questions posed to the students are detailed in Appendix B.

Three groups of students were randomly selected and divided according to the characteristics of courses they had previously taken. The first group consisted of students who had already attended the ESD elective course; the second group consisted of the tenth semester or final year undergraduate students who had not participated in the elective subject but had already gone through the entire academic curriculum offered by the undergraduate program. Finally, the third group consisted of students who had not opted for the elective subject and were randomly selected from those students who had not taken the subject but had progressed through several academic semesters within the program, excluding students in their tenth semester or final year.

The survey was conducted on students who did not take the ESD subject ($n = 38$) and students who took the ESD subject ($n = 32$), meaning that 70 students were surveyed of 182 who belonged to the environmental engineering program. Students who did not take the ESD course were divided into different courses or years, with a particular emphasis on the final year students, those who were about to graduate ($n = 6$). At this point, it is essential to clarify that, as mentioned in section b of the introduction, the subject formulated on ESD is elective, meaning that some students may or may not take it, depending on their preference.

3. Results

3.1. Survey Validity and Reliability

For the validation of the instrument, an initial survey was conducted on the test groups. Reliability was analyzed using Cronbach's alpha coefficient, which determines the internal consistency of a measurement instrument when several items are included [66]. The coefficient values vary from 0 to 1 and are divided into ranges that can be used to qualitatively interpret an instrument [67,68]. The professors' survey obtained an alpha coefficient of 0.77, while the students' survey obtained a value of 0.83. Therefore, it can be qualitatively stated that the internal consistency for both surveys was good. Likewise, the skewness and kurtosis coefficients were measured for all the responses. The total asymmetry was −1.84, and the kurtosis was 0.64. These indicate a negative asymmetry, indicating that most of the values selected in the survey are above the mean value of 3.3. On the other hand, the kurtosis was leptokurtic, which suggests a concentration of the response values around the mean.

There were some limitations to this study. The first was the unwillingness of universities to allow their students to participate in the survey. This meant that our research was limited to a single university for student responses. On the other hand, professors from several universities answered the survey, as it was much more freely available for them. Moreover, we could not determine the total sample size because some universities did not provide information on the total number of professors assigned to the environmental engineering program. However, this study presents these characteristics in terms of the number of students. It is feasible that new research seeks to broaden the surveyed base and expand the number of students to whom it is applied. On the other hand, in the professors' surveys, future studies must be proposed from the national level with more support. The search for political and economic support allows more teachers to be surveyed.

3.2. Results of the Environmental Engineering Professor Survey in Colombia

As shown above, the survey contains three questions with a multiple-choice format (Q1, Q2, and Q13) that do not consider the Likert scale. Regarding Q1, of the total number of respondents (n = 43), 90% of those who answered belonged to the environmental engineering undergraduate program (n = 39). The responses of the 39 professors were used for the results. Q2 aimed to establish which approach (practical, theoretical, or practical–theoretical) should be taken when teaching their classes, for which the following answer options were set: (a) make people responsible and aware of the knowledge of the environment and its problems; (b) involve people in the context, practices, and experiences of environmental problems perceived in their areas; (c) develop attitudes that help communities to strengthen their feelings of conservation and respect for nature and the environment, as well as their own culture; (d) develop skills that promote the search for solutions to current environmental problems and prevent those that may appear in the future; (e) encourage individual or collective actions to solve or prevent environmental problems. For this question, the results were 7% for option (a); 39.5% for option (b); 20.9% for option (c); 27.9% for option (d); 4.7% for option (e).

Q13 assessed the opinions of professors regarding the possible areas of EE or ESD competencies in the curriculum. The options were: (a) human sciences; (b) basic sciences; (c) basic engineering; (d) applied engineering. In this case, 39.5% answered option (d); 30.2% option (a); 16.3% option (c); and 14% option (b).

Table 2 shows the results and statistical values for the applied instrument, where f is frequency. First, the value for each item was determined, representing the sum of the values assigned to each response by the respondents. In other words, for this instrument, the maximum value per item was 156, which would be achieved if all people (n = 39) is assigned with a value of 4 (completely) to their answer.

Table 2. Statistical values for the professor's instrument.

Question	Value per Item	*Frequency*				Percentage			
		f (4)	f (3)	f (2)	f (1)	(%) 4	(%) 3	(%) 2	(%) 1
Q3	151	35	3	1	0	90%	8%	3%	0%
Q4	151	34	5	0	0	87%	13%	0%	0%
Q5	135	22	14	2	1	56%	36%	5%	3%
Q6	113	11	15	11	2	28%	38%	28%	5%
Q7	121	12	21	4	2	31%	54%	10%	5%
Q8	128	18	15	5	1	46%	38%	13%	3%
Q9	115	18	8	6	7	46%	21%	15%	18%
Q10	147	33	4	1	1	85%	10%	3%	3%
Q11	148	33	5	0	1	85%	13%	0%	3%
Q12	148	32	6	1	0	82%	15%	3%	0%
Q14	120	15	13	10	1	38%	33%	26%	3%
Q15	107	12	11	10	6	31%	28%	26%	15%
Q16	115	14	12	10	3	36%	31%	26%	8%
Q17	112	10	17	9	3	26%	44%	23%	8%
Q18	134	20	16	3	0	51%	41%	8%	0%
Q19	150	33	6	0	0	85%	15%	0%	0%
Q20	148	32	6	1	0	82%	15%	3%	0%
Q21	121	12	19	8	0	31%	49%	21%	0%

The questions were divided into two components, with Q3 to Q12 focusing on EE and the rest exclusively focusing on ESD. There was a significant change in frequency from Q14 onwards. It is essential to mention that the mean value was not used, as recent studies suggest not using this value for Likert scales [69]. The highest frequency value was 4 "completely" and the lowest was 1 "not at all" for most of the questions, except for Q6, Q7, Q17, and Q21.

3.3. Review of the Curriculum

The study plan for the environmental engineering program of the University of Santo Tomas has a focus on fulfilling the EE curriculum. In total, 77.76% of the surveyed students concluded that the subjects in basic sciences and applied environmental engineering are more EE-oriented. On the other hand, there is evidence of a lack of academic spaces and pedagogical strategies related to ESD within the curriculum. This could be due to the level of difficulty in recognizing the fundamental pillars and themes of ESD; however, by implementing an elective subject in the curriculum, the students who enrolled in this subject have a broader knowledge and a greater perspective of the ESD academic model. Regarding the areas of the program, ESD predominates in the area of applied basic sciences, which is why it is necessary to update the academic curriculum for this program. The curricular committee of the USTA Faculty of Environmental Engineering debated the results of the curriculum review and the surveys conducted over different sessions. As a result, an elective subject was proposed as part of the training options offered to 4th-year students. The syllabus for the ESD subject was designed by a group of professors from the program, including the authors of this article. Subsequently, it was submitted to the curricular committee of the faculty for its approval and implementation. Annex 3 shows the syllabus proposed for the subject called ESD.

3.4. USTA Environmental Engineering Student Survey Results

The result of the survey can be seen in Table 3. Questions Q1 and Q13 have not been included as they are dichotomous questions—they only have two possible answers (yes or no). Likewise, questions Q3, Q5, Q6, Q15, Q17, Q18, and Q26 have not been included in Table 3 as they are multiple-choice questions.

Table 3. Statistical values for the student's instrument.

Q	Students Who Did Not Take the ESD Course								Students Who Took the ESD Course				Statistics Indicators per Question			
	Students in General				Final Year Students				Fourth-Year Students							
	Percent (%)				Percent (%)				Percent (%)				Asymmetry	Kurtosis	St.D	MED
	1	2	3	4	1	2	3	4	1	2	3	4				
2	0.0	9.4	65.6	25.0	0.0	16.7	16.7	66.7	0.0	3.1	21.9	75.0	−0.51	−0.61	0.61	3.36
4	6.3	31.3	40.6	21.9	0.0	0.0	16.7	83.3	3.1	3.1	25.0	68.8	−0.87	−0.09	0.88	3.06
7	0.0	9.4	46.9	43.8	0.0	0.0	33.3	66.7	0.0	3.1	18.8	78.1	−1.06	0.12	0.61	3.50
8	3.1	0.0	46.9	50.0	0.0	0.0	33.3	66.7	0.0	0.0	34.4	65.6	−1.25	2.91	0.57	3.50
9	0.0	0.0	25.0	75.0	0.0	0.0	33.3	66.7	0.0	0.0	15.6	84.4	−1.33	−0.23	0.42	3.75
10	0.0	6.3	37.5	56.3	0.0	0.0	50.0	50.0	0.0	6.3	18.8	75.0	−1.00	0.02	0.61	3.49
11	0.0	12.5	53.1	34.4	0.0	0.0	50.0	50.0	0.0	6.3	15.6	78.1	−0.78	−0.46	0.66	3.37
12	6.3	12.5	43.8	37.5	0.0	33.3	50.0	16.7	3.1	6.3	34.4	56.3	−0.83	0.06	0.85	3.03
14	0.0	3.1	62.5	34.4	0.0	0.0	16.7	83.3	0.0	0.0	12.5	87.5	−0.86	−0.36	0.54	3.55
16	0.0	3.1	34.4	62.5	0.0	0.0	16.7	83.3	0.0	3.1	15.6	81.3	−1.79	2.47	0.49	3.71
19	0.0	3.12	31.2	65.6	0.0	0.0	50.0	50.0	0.0	0.0	12.5	87.5	−1.30	0.48	0.48	3.68
20	0.0	6.25	56.2	37.5	0.0	0.0	33.3	66.6	0.0	12.5	15.6	71.8	−0.82	−0.37	0.65	3.40
21	0.0	6.25	40.6	53.1	0.0	0.0	16.6	83.3	0.0	0.0	21.8	78.2	−1.22	0.26	0.49	3.67
22	0.0	0.0	28.1	71.8	0.0	0.0	16.6	83.3	0.0	3.1	15.6	81.3	−1.54	1.32	0.46	3.72
23	0.0	6.25	46.8	46.8	0.0	16.6	16.6	66.6	0.0	0.0	37.5	62.5	−0.86	−0.36	0.54	3.55
24	0.0	9.37	40.6	50.0	0.0	0.0	33.3	66.6	0.0	0.0	25.0	75.0	−1.13	0.32	0.56	3.57
25	0.0	6.25	31.2	62.5	0.0	0.0	50.0	50.0	0.0	0.0	9.3	90.6	−1.53	1.46	0.50	3.67
27	15.6	21.8	43.7	18.7	0.0	16.6	83.3	0.0	18.7	25.0	31.25	25.0	−0.35	−0.67	0.93	2.49
28	28.1	34.3	34.3	3.12	16.6	16.6	50.0	16.6	53.1	25.0	15.6	6.2	0.27	−1.10	0.97	1.88
29	0.0	0.0	43.7	56.2	0.0	0.0	50.0	50.0	3.1	3.1	15.6	78.1	−1.68	3.48	0.60	3.55
30	3.12	15.6	40.6	40.6	0.0	16.6	50.0	33.3	3.1	15.6	25.0	56.2	−0.93	0.08	0.84	3.13
31	21.8	34.3	37.5	6.25	16.6	33.3	33.3	16.6	40.6	37.5	9.3	12.5	0.32	−0.99	1.01	1.99
32	21.8	40.6	31.2	6.25	0.0	83.3	0.0	16.6	53.1	25.0	9.3	12.5	0.46	−0.86	1.00	1.90
33	3.12	12.5	37.5	46.8	0.0	16.6	50.0	33.3	0.0	6.2	15.6	78.1	−1.09	0.33	0.81	3.26
34	9.37	21.8	34.3	34.3	0.0	0.0	66.6	33.3	6.2	18.7	21.8	53.1	−0.78	−0.39	0.92	2.98

Of the 32 students who took the ESD course, none had prior knowledge of ESD; however, the entire sample claimed to understand the importance of ESD. The most common quantitative values for the Likert scale ranged from 3 to 4 for the related questions. The results for Q3 show that most tenth semester or final year students and those who had not taken the ESD elective did not know about the three pillars of SD (economy, society, and environment). On the other hand, students who took the elective ESD subject had a better knowledge of the SD pillars.

Question Q4 referred to the SDGs. In this case, it seems that most of the students had heard about these objectives. Q5 presented a particularity in the results because, although climate change is an important issue within ESD, it relates more to EE than ESD. Likewise, more than 60% of the students chose topics related to drinking water and changing consumption patterns, leaving aside problems related to human settlement, social transformation, and poverty.

For question Q6, the students showed similar inclinations towards EE and ESD concepts, with the highest percentages corresponding to the answer "to minimize the use of non-renewable resources", which is more in line with conservation efforts in EE. On the other hand, they also favored the answer "to control the state of natural resources, the environment, and the well-being of human beings". Again, this option leans more towards sustainable development and ESD.

Regarding Q7, most students know that overconsumption and environmentally harmful production behaviors must be reduced and eliminated to achieve sustainable development. When students were asked about unsustainable practices and the impact of local and global environmental problems in question Q8, all students agreed that to achieve SD, harmful environmental practices must be eliminated and local problems must be minimized. Question Q9 showed that all students generally agreed on the need to preserve natural resources to achieve SD. In this sense, there is an inclination towards conservationism, moving away from SD. The results in this question reflect the confusion and mixing of concepts related to ESD and EE that students have.

Most students agreed that they had received relevant instructions and education to become engineers throughout their degrees, favoring inclusion, equality, peace, and tolerance, with a comprehensive vision of the environment, as evidenced in question Q10. In question Q11, most students stated that ESD enables the creation of ecologically critical reading and interpretation skills; however, these students were unaware of the ESD principles, as the ecological perspective is closer to the principles of EE. On the contrary, all students recognized the need for professors to be more trained in the principles that promote SD, as evidenced in question Q12.

Most of the analyzed results showed that the students understood the EE model. However, when choosing EE-related topics, almost all students wrongly elicited practices of socio-economic, environmental, and sustainability balance, which are ESD issues. The students in the last academic year were more knowledgeable about these topics, as shown in questions Q13 and Q15. Question Q14 determined whether all of the students had a clear understanding of EE. Regarding Q16, most students recognized the importance of the contents of the EE model.

Question Q17 referred to the objectives of the EE model, showing that more than 70% of students agreed on issues related to "raising awareness about environmental problems"; "promoting participation and improvement of the environment"; and "encouraging people to become more educated about the environment and to carry out activities related to energy, landscape, air, water, and wildlife".

Accordingly, students were aware of the objectives of EE; in that sense, in question Q18, the students emphasized that EE aims to support the development of an ethic that promotes the protection of the environment from a perspective of equality and solidarity. Regarding question Q19, students generally considered that their degree provides them with the knowledge needed to constructively face the challenges of humanity, such as population growth, life cycles, and biodiversity, among others. According to the results obtained for question Q20, most students agreed that they had not received enough classes and pedagogical workshops in ESD or EE. Meanwhile, the 10th semester and final year students agreed that they had been successfully trained in EE-oriented concepts and actions. Students in general considered EE to be characterized by a dialectical process (argumentation) that reflects the quality of life of communities and their permanent connection to environmental balance. Said relationship is based on early actions influenced by environmental awareness, such as the recycling of bottles and plastic bags, as expressed in questions Q21 and Q23.

On the other hand, question Q22 referred to environmental issues, including the emergence of global-scale phenomena such as climate change and the greenhouse effect. The students responded affirmatively to this question and had a clear vision of the environmental problems that EE should address.

Regarding Q24, more than 90% of the surveyed students expressed the importance of multiculturalism, a characteristic feature of both ESD and EE. Multiculturalism is one of the most important factors to achieve the SDGs, representing a characteristic feature of ESD [70]. Likewise, EE has historically promoted multiculturalism since its inception. Therefore, it can be ensured that students have a clear knowledge about this concept for both EE and ESD.

For Q25, most respondents stated that the educational transition process has ceased to be an end in itself, and that it has become an instrument to promote the changes necessary to achieve SD. In addition, most of the students stated that they had experienced direct contact with ESD at the time of the survey, as noted in the results for question Q26.

Question Q27 was notable in that most students did not know that there was a different approach to EE; that is, they were unaware that there are alternatives to EE, such as ESD. Regarding Q28, most of the students who had not taken the ESD elective subject and 50% of the final year students agreed that they would prefer an EE subject over the ESD one, while the students who took the ESD elective and the remaining 50% of final year students favored the ESD course. In Q29 and Q30, most students who took the ESD elective subject felt that it was important for the population of Colombia to receive more ESD training. Regarding students who had not taken the ESD elective subject and those in their final year, the transition from EE to ESD was less crucial than for those who took the elective subject.

According to the results obtained for question Q31, there were different opinions among students regarding the preference for the EE model over the ESD one, since some wanted more EE topics to be taught, while others would have liked to focus on ESD. Regarding Q32, approximately 60% of the students who had not seen the ESD course preferred the EE model, while last year students and those who had taken the ESD course preferred the ESD model.

Finally, for Q33 and Q34, all the students thought that both ESD and EE should be transversal throughout their environmental engineering degrees, meaning strategies should be designed to achieve SD and environmental conservation actions.

4. Discussion and Conclusions

The conclusions are in the frame of the limitations mentioned in the previous sections. It is important to emphasize that this study can be taken as a guide to carry out similar processes within programs in environmental engineering and other disciplines. Therefore, the conclusions, reflections, and discussions are not proposals for a generic application within the HEIs, but they shed light on how to address the issue of the inclusion of ESD in engineering curricula.

In general, the professor surveys avoided the analysis of individual items or questions, except in some relevant cases where the answers to some questions were highlighted. This approach was based on the recommendations of Harpe (2015) for this type of instrument involving a Likert scale. It was found that professors have a great affinity and knowledge of EE in Colombia [71]. This result is possibly associated with the great support that EE has historically had in Colombia from the public and private sectors [Author(s)]. The survey responses showed that professors had knowledge and clarity about the concept of EE; however, this same survey showed some gaps in knowledge regarding ESD and SD, as can be seen in Table 2 and Figure 3. As for the students' responses, they had greater clarity on the topics and concepts of EE.

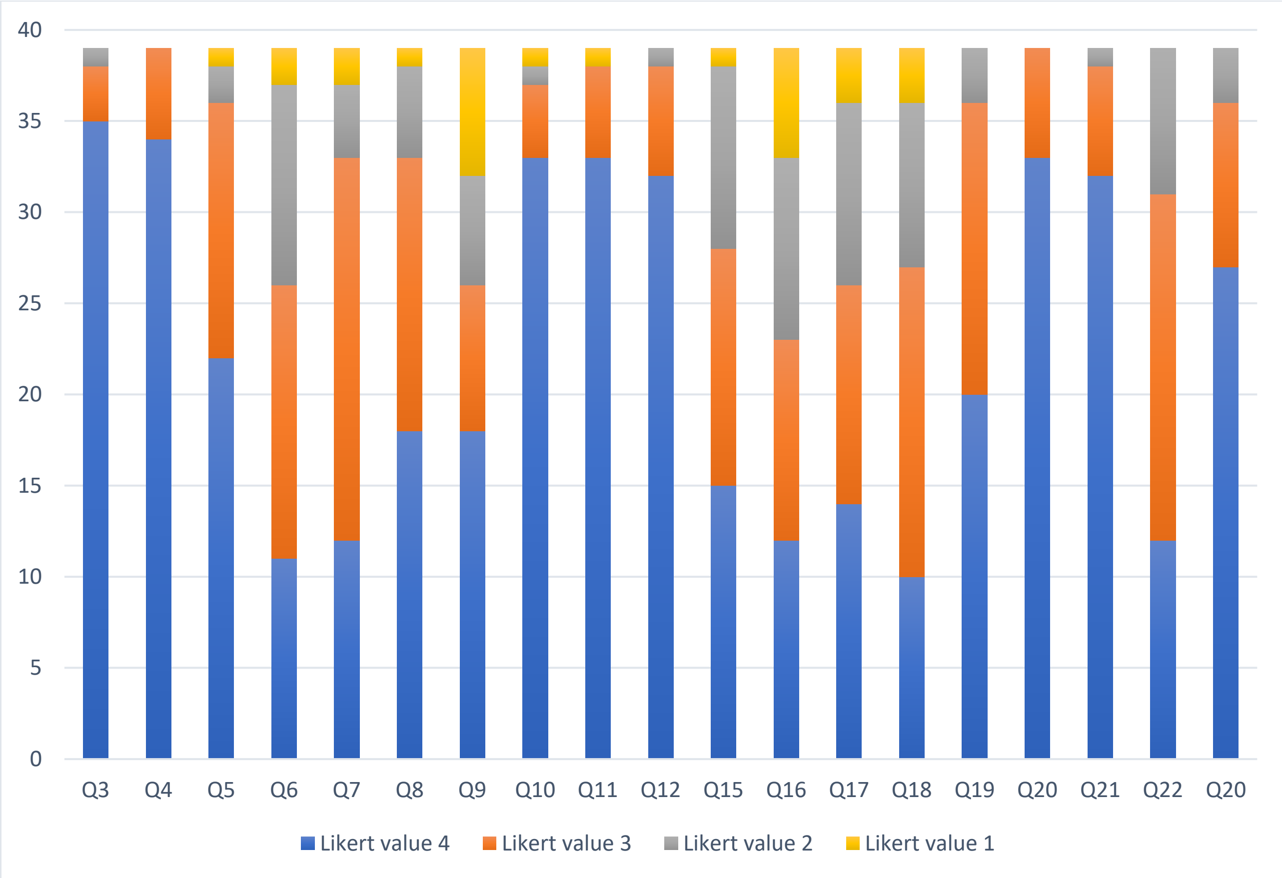

Figure 3. Professors' responses.

In this sense, there are some gaps in the teaching of environmental engineering compared to the knowledge of SD. Likewise, there is a lack of clarity in universities regarding the fact that ESD is the best model to achieve the SDGs [10]. This study showed the lack of momentum that SD has in different sectors of the governmental bodies, including educational institutions. The lack of promotion of SD in Colombia is reflected in the little progress that this country has made compared to other Latin American countries [72]. Colombia recently ranked ninth out of 12 countries in the Latin American region in terms of the scope of the SDGs [73].

It appears that professors were unclear about the concept of ESD and its importance. For example, for Q14, only 38% of professors fully understood ESD, 59% thought they lacked some knowledge, and 3% did not understand it. On the other hand, for Q16, professors were not clear about the differences between EE and ESD. This could have been caused in part to the mixing of concepts and methodologies. This confusion or overlap of theories is transmitted to the students. In turn, this can generate a conflict between the SD model and the conservationist model promoted by the EE.

Furthermore, this can cause students to take an uninformed position, as they might not clearly understand the differences, advantages, and disadvantages of EE or ESD. All of this represents an opportunity for improvement, especially in universities. Professors play a fundamental role in the expansion of ESD [74] and, therefore, universities should strive to train them in SD to avoid the biases, overlaps, and gaps between EE and ESD. Professors play a fundamental role in adapting to the ESD model, since they can provide theoretical and practical guidance so that students are more knowledgeable in sustainability [75]. In addition, universities must have a complete and comprehensive vision of reality, taking into account the social, economic, and environmental transformations that are taking place around the world [37]. To achieve this, universities must restructure their curriculum and include subjects or courses that are oriented towards achieving peace, social and food security, global changes, development, and environmental protection [76].

The generation of conceptual gaps due to the incomplete transmission of information could be a result of this country not having an updated environmental education policy or a policy focused on teaching current and future generations how to achieve SD. The "Environmental Education Policy" document from 1994 [77,78] has a clear protectionist motivation and urges educational entities of all kinds, from primary schools to universities, to implement the EE model. On the other hand, no government document promotes ESD in this country. All of this makes it difficult for universities to promote SD and, in turn, become a catalyst for achieving the SDGs. Some universities have responded to labor needs by ensuring graduates are literate in SD [12]. Unfortunately, according to the results obtained in environmental engineering in Colombia, this is not being achieved.

It is important to note that professors see the benefits of adding an ESD-related subject within the environmental engineering program. The corresponding questions were Q12 and Q20. In both cases, 82% fully agreed that the curriculum should be permanently modified, which also opens up the need to adapt the curriculum and incorporate some aspects of ESD [79]. To properly achieve this, professors must be prepared and trained in SD [80].

In general, environmental engineering students have a significant commitment to society. This has been evidenced through their support for activities with a strong social and environmental commitment, compared to other engineering fields. In order to lead and strengthen this ability in environmental engineering students, the curricular update should be sought, where subjects focus on knowing and learning about topics such as the SDGs and the ways to achieve SD in a country such as Colombia Author(s) [75].

Interestingly, only 45.56% of the students surveyed claimed to understand ESD, which is the same percentage of students who took the ESD elective subject. These results can be evidenced in Table 3 and in Figure 4. Therefore, the results allow us to conclude that ESD is practically absent from the USTA training programs for environmental engineers. In addition, when comparing the results obtained with those of other studies, we find that the same gap is present in other Colombian universities [56,78,81–84].

The lack of knowledge about SD in universities, especially in engineering, can delay achieving the SDGs in Colombia [85]. It is important to note that most students who have taken the ESD elective subject consider it essential to be trained to help achieve SD. Therefore, they must be cross-trained in social, economic, and social matters.

It was possible to corroborate the results of previous studies and contribute to fill the gaps in the incorporation of SD into the curriculum at universities [86]. The identified gaps are the following: (1) lack of awareness of the relevance of SD [87,88]; (2) lack of proper adjustments and support to make changes [87]; (3) insecurity and professors not teaching the interdisciplinary courses necessary for ESD [89]; (4) the existence of "ornate circles" [89]; (5) professors not supporting the dissemination of information on this subject [90,91].

The student survey was the primary way of identifying both the contributions and the shortcomings of EE and ESD. One of the study's most significant findings was the influence of the teaching staff on their students in promoting environmental awareness and recognizing environmental phenomena. In this sense, one of the essential concepts that must be reinforced in students is understanding the harmony of the factors that make up the SD: society, economy, and the environment. To achieve this, it is necessary to train students and involve them in activities that encourage and promote SD [92].

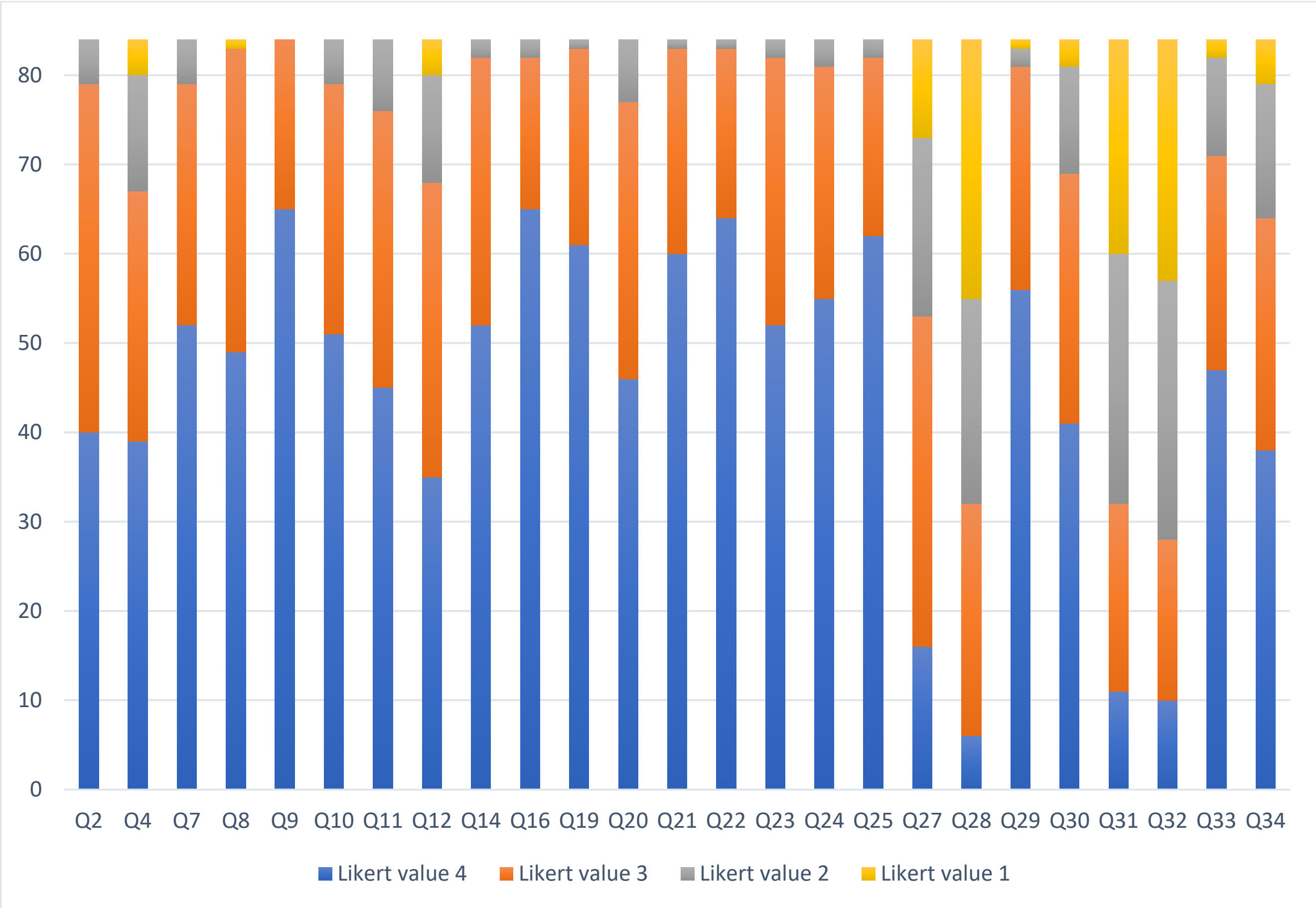

Figure 4. Results of students' responses.

The creation of the ESD subject was not only in response to the problems highlighted in the two surveys in this paper, but also to the global challenges to improve engineering curricula [93]. It is essential to mention that, in the bibliographic review carried out in databases such as Scopus, Science Direct, and WOS, no evidence was found of the incorporation of ESD in an undergraduate program in environmental engineering. At the same time, we found interesting cases such as the one at the Tecnologico de Monterey (Mexico) involving a program called "Engineering for Sustainable Development". Within this curriculum, there is a subject dedicated solely to teaching SD [86]. In this sense, there was research evidence on the importance of incorporating ESD into curricula to face the challenges of achieving the SDGs [94,95].

With this research, the USTA undergraduate program in environmental engineering proposed a solution to the knowledge gap in its students regarding SD. Although the proposal is the addition of a subject, it cannot be the only option within a higher education program.

Therefore, curricular and pedagogical strategies must be developed to engage the student and other university actors so that knowledge of SD is generalized and transversal. However, adding an elective subject can only impact those who take it, as was reflected in this research. Nevertheless, it is perhaps the fastest and easiest way to change the way that ESD is taught and incorporated into curricula. Including a compulsory subject, a transformation can initiate a change in the very concept of engineering education, where future professionals are aware of their work concerning the environment and society.

On the other hand, this research could potentially reflect what happens in other universities in Colombia and globally, generating uncertainty in achieving SD through the SDGs in developing countries [96].

For this reason, it is important to continue researching this issue in universities, promoting curricular updates in technical or specific issues of each degree. Institutions should study the possibility of incorporating SD in the curriculum, following the example of the incorporation of ethics within the curricula. Likewise, it is necessary to investigate how to take advantage of the high level of EE knowledge in Colombia and Latin America and incorporate new models, such as "environmental education for sustainable development", which reconcile the developmental aspects of SD and the conservationist aspects of EE.

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Appendix A

Table A1. Survey conducted on university professors specializing in environmental engineering.

No.	Question	No.	Question
Q1	Are you or have you taught an undergraduate program in environmental engineering?	Q12	Do you think it is important that environmental education be involved within the environmental engineering program curriculum?
Q2	Of the objectives of environmental education, please indicate which one you consider would be the most important for an environmental engineer.	Q13	In your opinion, in which of the following academic contexts of the structure of the training of an engineer should environmental education be oriented?
Q3	How important do you think Environmental Education is for an environmental engineer?	Q14	How well do you know the concept or current of Education For Sustainable Development?
Q4	How important is Environmental Education to you as a person?	Q15	Have you ever applied Education For Sustainable Development in your classes or subjects?
Q5	As a professor of the environmental engineering program, do you think you train your students in the concepts or principles of Environmental Education?	Q16	Do you know the differences between Environmental Education and Education for Sustainable Development?
Q6	Do you consider that there are sufficient academic spaces (subjects) in the study plan where the environmental engineering student is trained In Environmental Education?	Q17	In your opinion, do you think that Education For Sustainable Development focuses on actions for the environment?
Q7	Do you consider that within the contents of the subject (s) that you teach, the student is trained in Environmental Education skills?	Q18	In your opinion, do you think Education For Sustainable Development focuses on cultural, social, economic, and biological diversity?
Q8	Have you carried out Environmental Education activities in your role as an environmental engineering professor?	Q19	Do you think Education For Sustainable Development is important within the field of action of the environmental engineer?

Table A1. *Cont.*

No.	Question	No.	Question
Q9	Have you ever been trained or guided in Environmental Education strategies outside of academic training activities?	Q20	Do you think it is important that Education For Sustainable Development be included within the Environmental Engineering program curriculum?
Q10	Do you think that within the field of action of the environmental engineer it is important to obtain tools to develop Environmental Education actions?	Q21	As an engineering professor, do you think you train your students in Education For Sustainable Development principles?
Q11	Would you like to be part of the formulation and implementation of environmental education projects?		

Appendix B

Table A2. Questionnaire given to environmental engineering students.

No.	Question	No.	Question
Q1	Have you taken or are you taking the subject Education For Sustainable Development?	Q18	Environmental Education aims among other things:
Q2	Am I clear about the concept of Education For Sustainable Development?	Q19	Am I clear that the degree I am studying provides me with the knowledge to constructively confront the challenges of humanity?
Q3	Education for Sustainable Development currently has three main pillars for its implementation. Which of the following approaches do you think are these pillars?	Q20	Have I received classes, workshops, or pedagogical exercises within the subjects of my degree that involve concepts or actions around Environmental Education?
Q4	Am I clear about the Sustainable Development Goals (SDGs) proposed by the UN?	Q21	Do I consider that the recycling of bottles and plastic bags are actions that are aimed at the pedagogy of Environmental Education?
Q5	Which of the following issues do I consider to be part of the Education for Sustainable Development model?	Q22	Do I consider that the present environmental crisis is characterized by the appearance of global phenomena such as climate change, the greenhouse effect, the thinning of the ozone layer, and the loss of biodiversity; are these issues that should be taken into account in the themes of Environmental Education?
Q6	To achieve sustainable development, I think it is necessary…	Q23	Do I consider Environmental Education to be a dialectical process (argumentation) that reflects the quality of life of communities and their permanent relationship with environmental balance, based on early actions influenced by environmental awareness?
Q7	Do I believe that to achieve sustainable development, nations must reduce and eliminate unsustainable patterns of production and consumption and promote appropriate population policies?	Q24	Do I consider that to approach and intervene in environmental problems, it is necessary to take into account the multiculturalism that each country protects as a patrimonial treasure that identifies it, based also on the principles of Environmental Education?
Q8	Do I believe that local environmental problems can have a global impact?	Q25	I consider that in the process of transition, education ceases to be an end in itself and becomes an instrument, a means to promote the necessary changes to ensure sustainable development.

Table A2. *Cont.*

No.	Question	No.	Question
Q9	Am I convinced that conserving natural resources is an essential pillar for achieving sustainable development?	Q26	For me, is the concept of Education for Sustainable Development something new, something I have just come into contact with?
Q10	Do I feel that I have received the instruction and education to become a future engineer who seeks equity, peace, tolerance, and inclusion?	Q27	Before the subject Education for Sustainable Development, did you only think that there was an Environmental Education approach?
Q11	Is it clear to me that Education for Sustainable Development allows for the creation of critical reading and interpretation skills?	Q28	Do I prefer the subject of Environmental Education to the subject of Education for Sustainable Development?
Q12	Do I think that professors need more training to promote the principles of sustainable development within the subjects I have already studied?	Q29	Am I clear that Colombia and the world must make a transition from Environmental Education to Education for Sustainable Development to achieve the Sustainable Development Goals?
Q13	Have you taken any subjects or been trained in courses in Environmental Education?	Q30	Do I think that for Colombia it is more necessary to be trained in Education for Sustainable Development instead of Environmental Education, since Education for Sustainable Development links the social, economic, and environmental? In contrast, Environmental Education promotes conservation, meaning a focus on Environmental Education would not help achieve sustainable development?
Q14	Am I clear about the concept of Environmental Education?	Q31	Do I think it is more appropriate for Environmental Engineering to learn about Environmental Education than Education for Sustainable Development?
Q15	To disseminate the practices of Environmental Education, I consider it necessary to implement issues related to biodiversity...	Q32	Am I convinced that I prefer Environmental Education to Education for Sustainable Development?
Q16	Does the importance of knowing the contents of Environmental Education help us to know which path to take when educating new generations to achieve more sustainable development?	Q33	Do I think that Education for Sustainable Development should be transversal to my entire engineering career; that is, that all subjects will focus on sustainable development?
Q17	Among the following items, which do you think refer to the objectives of Environmental Education?	Q34	Do I think that Environmental Education should be transversal to my entire engineering career; that is, that conservation actions will be focused on all subjects?

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