

From environmental education to education for sustainable development in higher education: a systematic review

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Abstract

Purpose – In education concerning environmental issues, there are two predominant currents in the world, environmental education (EE) and education for sustainable development (ESD). ESD is the formal commitment and therefore promoted by the United Nations, to ensure that countries achieve sustainable development. In contrast, EE was the first educational trend with an environmental protection approach. The purpose of this systematic review that seeks to show whether the migration from EE to ESD is being effective and welcomed by researchers and especially by universities is presented. With the above, a global panorama can be provided, where the regions that choose each model can be identified. In the same sense, it was sought to determine which of the two currents is more accepted within engineering education.

Design/methodology/approach – The review followed the preferred reporting items for systematic reviews and meta-analyzes parameters for systematic reviews. In total, 198 papers indexed in Scopus, Science Direct, ERIC and Scielo were analyzed. With the results, the advancement of ESD and the state of the EE by regions in the world were identified.

Findings – It was possible to categorize the geographical regions that host either of the two EE or ESD currents. It is important to note that ESD has gained more strength from the decade of ESD proposed by the United Nations Educational, Scientific and Cultural Organization. For its part, EE has greater historical roots in some regions of the planet. In turn, there is evidence of a limited number of publications on the design and revision of study plans in engineering.

Originality/value – Through this systematic literature review, the regions of the world that are clinging to EE and those that have taken the path of ESD could be distinguished. Moreover, specific cases in engineering where ESD has been involved were noted.

Keywords Environmental education, Higher education, ESD, Education for sustainable development, Engineering education

Paper type Research paper



1. Introduction

The terrestrial systems present a series of alterations that are the result of human actions from the Anthropocene era (Steffen *et al.*, 2015). Human behaviors are causing changes in the entire global environment creating an imbalance in the earth system, which can have

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catastrophic consequences for certain parts of the planet (Rockström *et al.*, 2009; Scheffer *et al.*, 2001). Some problems, such as global anthropogenic climate change (GACC), which is the result of greenhouse gas emissions (Bush *et al.*, 2017; Muftakhova *et al.*, 2020), associated with excessive population and economic growth, threaten the future outlook for human species and the planet's biodiversity (Bongaarts, 2016).

It is difficult to solve these environmental problems only by considering relevant scientific research and sharing the results with decision-makers (Ardoin *et al.*, 2020; Lemos *et al.*, 2018; Toomey *et al.*, 2017). It is, therefore, necessary to involve all levels of society. To ensure that everyone is achieved, different strategies are needed. Perhaps the first formally used strategy was environmental education (EE) (Acosta Castellanos *et al.*, 2020; Hyde and Karney, 2001; Marouli and Duroy, 2019). EE is deeply rooted in the relationship that human beings have with nature and EE seeks to generate awareness in people for their care and protection (Kopnina, 2015; Liu, 2018). EE is a strategy that seeks conservation through knowledge, experience, values and local practices (Ardoin *et al.*, 2020; Toomey *et al.*, 2017).

Therefore, EE can be seen from many approaches and on different scales, from the individual to the collective, as seeking to improve people's behavior toward nature (UNESCO, 1977; West, 2015). In summary, this trend responds to the complexity of the environment and its union with biological, physical, social, cultural and socioeconomic factors, focusing on promoting ecological behaviors and critical thoughts in the face of excessive consumption (García and Ruiz Morón, 2008; Marcinkowski and Reid, 2019). EE can have marked political features and it is the basis for ideas that can go against global stakes, such as sustainable development (Hursh *et al.*, 2015). Several uncertainties still haunt EE, particularly in a globalized world where nature is little known and where it is often replaced by alternate realities, such as virtual reality, as it is difficult to believe in and protect something that is not known (Ekpiken and Ukpabio, 2015); this becomes an act of "faith."

The current counterpart of EE is education for sustainable development (ESD), which is based on the concept and model of sustainable development presented at the United Nations General Assembly on August 4, 1987, in the report entitled "Our Common Future," also known as the Brundtland report. In this report, EE was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

From then on, all the nations that had not achieved economic and social development pointed to this model, which seeks a balance that inevitably involves the environment, as intergenerational equity is not possible without taking this factor into account (Waas *et al.*, 2014). It is difficult to find a consensual path that marks the route to achieve this model of development. Different strategies have been proposed by the UN; the last one is the formulation of series of guidelines to be achieved by the Nations, called sustainable development goals (SDG) (Biasi *et al.*, 2019).

Among these goals is "quality education," with the purpose to apply the ESD model. This model seeks to empower and promote democratic participation by harmonizing the economic, environmental and social aspects (Ekpiken and Ukpabio, 2015; Kopnina, 2014). ESD typically focuses on harmony between the environmental risks and benefits and ensures the provision of natural resources for future generations (Colombo *et al.*, 2015). One of the differences between ESD and EE is that ESD shows a greater inclination toward the human being as the axis of the environment; ESD includes, therefore, education for peace, education on human rights and education for health, gender education and inclusive education among others (Balls, 2016; Colombo *et al.*, 2015; Wals and Arjen, 2012).

With this holistic approach, ESD aims to be the cornerstone to achieve the 17 SDG (UNESCO, 2017). There are various criticisms of ESD, in particular for its anthropocentric approach (Bonnett, 2013; Koppina, 2014). The proclamation of the “2030 Agenda” welcomed by the 193 member states of the UN, makes ESD unavoidable for member states and, therefore, should promote the necessary transformations so that education institutions from primary up to higher education incorporate ESD (Rendón López *et al.*, 2018; UNESCO, 2017).

In this ambitious context, universities play a leading role to ensure that their efforts in research, social responsibility and the curricula involving ESD have the aim of creating awareness and educating students to achieve sustainable development (Bagoly-Simó *et al.*, 2018; Glover *et al.*, 2013). Engineering, within the broad spectrum of higher education, has a great responsibility in sustainable development as a large part of technological and infrastructure advances are carried out by engineers (Colombo *et al.*, 2015; Soria *et al.*, 2013a; Svanström *et al.*, 2018).

Based on the above, this study sought to answer three research questions regarding ESD and EE; through a systematic review in the databases of Scopus, Science Direct, ERIC and Scielo:

- Can the existence of the transition from EE to ESD be demonstrated from the invitations to host this model by the UN?

This question seeks to address the advancement of the ESD versus its counterpart, the EE. If the research in EE is greater when taking into account the UN proposals to embrace the ESD, this could indicate deficiencies in the process of the disclosure of this methodology. If, on the contrary, based on the UN proposals, more research is being done on ESD, this would indicate that it is a wise bet and, therefore, accepted by the scientific community.

- Can we identify a geographic region where research is continuing under an EE approach that indicates resistance to the transition to ESD?

This question seeks to identify which regions have more progress in ESD, assuming that, the more research, the greater the acceptance of this form of education. This may be associated to the economic characteristics and development of each region.

- In what way can the inclusion of ESD be demonstrated in the undergraduate curricula of higher education and, more specifically, in engineering teaching?

In this case, the aim was to identify good practices for integrating ESD in universities and whether future professionals will be aligned with the sustainable development model. Thus, some universities may be better preparing their students for the challenges posed by sustainability in environmental terms.

2. Methodology

Based on the research questions, to carry out a systematic review of the literature, the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) method was followed (Moher *et al.*, 2009). The period of time that was considered for searching for publications was from 1987 because this was the year in which the theory of sustainable development was presented (Hallinger and Nguyen, 2020), until 2020, more specifically until June.

The population, intervention, comparison, outcome and context framework was applied to determine the scope of the research developed in this study. Population: research developed in EE since 1987. Intervention: geographical location, number of studies, date of studies, engineering studies and higher education. Comparison: the acceptance of ESD

against the acceptance of EE. Outcome: to determine the status of the progress and transition process to ESD in higher education, with a special emphasis on engineering education. Context: higher education.

2.1 Search criteria and source identification

The first database that was searched was Scopus, due to its widespread use and its multidisciplinary context with high-quality standards. Likewise, Science Direct was chosen due to the relationship that this database has with publications focused on engineering. ERIC is another database that was chosen for its focus on education publications. Finally, Scielo was chosen to include a database with great acceptance in Latin America and of a multidisciplinary nature. With this selection of databases, a wide range of publications and geographic areas were covered.

For the four databases, the same selection criteria were taken and only studies published in journals, book chapters and books were considered; any other type of publication that appears in these databases, such as proceedings, did not enter in the review process. The reason was that not all the databases include proceedings within their information. With that, it was sought to have a greater homogeneity in the data. As an important factor, the search was limited to documents written in English or Spanish and the exact search for the keywords “Environmental Education” or “Education for Sustainable Development,” and both in Spanish. The acronyms were also considered, education for sustainable development, EE and ESD.

The general search equation in English was as follows: *TITLE (“environmental education” OR “Education for sustainable development”) AND DOCTYPE (ar OR re) AND PUBYEAR > 1986 AND PUBYEAR < 2021 AND (LIMIT-TO (LANGUAGE, “English”) OR LIMIT-TO (LANGUAGE, “Spanish”)) AND (LIMIT-TO (EXACTKEYWORD, “Environmental Education”) OR LIMIT-TO (EXACTKEYWORD, “Education For Sustainable Development”)) AND (LIMIT-TO (EXACTKEYWORD, “Higher Education”) OR LIMIT-TO (EXACTKEYWORD, “Engineering Education”)).*

The equation was refined and contextualized to give edge conditions so that the results were only focused on higher education or engineering. Within the quality criteria, as can be seen in [Figure 1](#).

2.2 Analysis of data

The final number of selected papers was 190, after the inclusion and exclusion filters and the other steps described in [Figure 1](#). They were ordered and coded to extract information to answer the research questions posed in this review. A checklist was made to evaluate specific quality criteria to identify the results with the greatest relationship to the research questions, different from the inclusion and exclusion criteria already mentioned.

A rating was assigned with answers of yes, partially and no, with weights of 1, 0.5 and 0, respectively, where 1 was a result totally related to the research questions, 0.5 is for results partially related – for example, papers that include EE in special education and higher education and finally, 0 was for papers related to the topic in general but not to the research questions. To make this classification, it was necessary to make a careful and conscientious reading of the summaries, to later extract the information necessary to answer the research questions.

Data extraction was performed with a careful and complete reading of the papers, as well as a free-form note-taking format with the information of each item with the highest score. The data to be extracted were the year, whether the paper included experiences of EE in engineering education, the geographic location, whether the paper was about EE, whether the paper included ESD experiences in higher education, whether the paper included EE

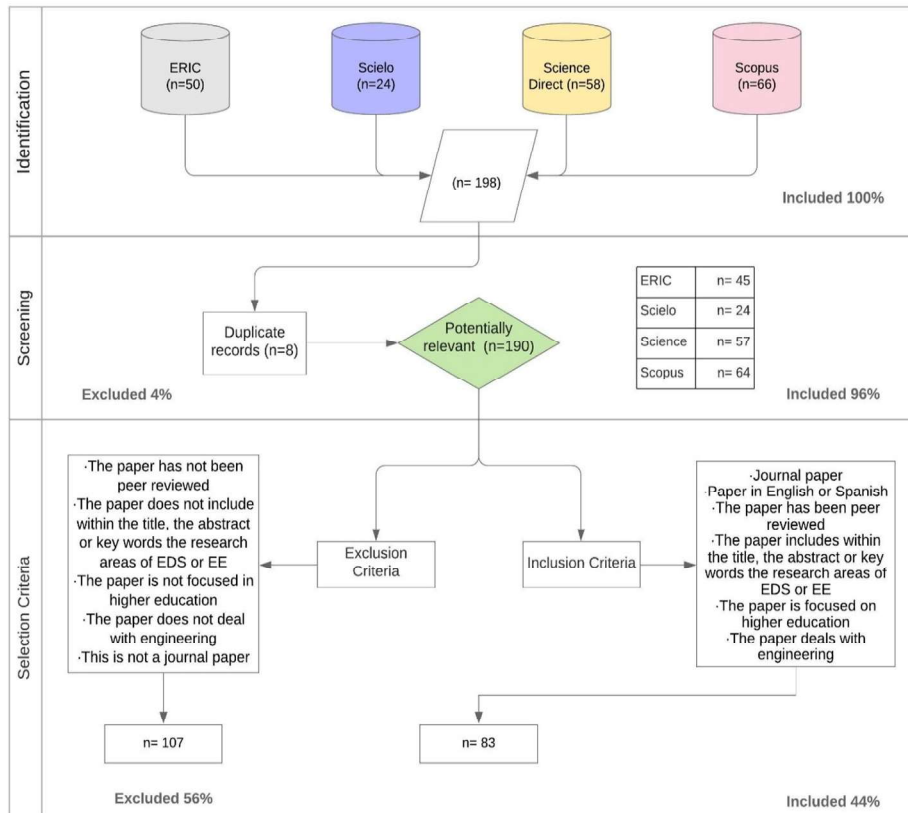


Figure 1. Flow diagram of the methodological process adapted from the one suggested by PRISMA and related to ESD

experiences in higher education, whether the paper was about ESD, whether the paper raised ESD and EE as a synonym and whether the paper included experiences of ESD in engineering education.

3. Results

According to the three research questions, the review results were split into three subsections, each of them related to the research questions and the data extracted.

3.1 Transition from environmental education to education for sustainable development

The review of the literature around the two lines of study of EE and ESD yielded striking results regarding the expected transition from EE to ESD. In Figure 2 the timeline of published papers in the three databases per year is shown. The decade for ESD proposed by United Nations Educational, Scientific and Cultural Organization (UNESCO) began in 2005 and ended in 2014 (Grabovska and Grabowski, 2009). The growth in the number of publications on ESD since 2013 is evident, with a peak of $n = 12$ publications in 2015 dedicated to this trend. Since 2014, except in 2017, the number of publications in this stream has been greater than for EE. The databases did not have any results between 1987 and 1997.

From the results, there were two of them dedicated to the analysis of the decade for ESD, one of them includes an analysis of the decade for ESD, before the end of the period proposed by UNESCO in different higher education institutions in Latvia (Grabovska and Grabowski, 2009). In this sense, Filho *et al.* (2015), made a greater analysis of the decade for ESD from a very generic perspective and highlighted progress in the application at the global and regional levels. To review the trend and the number of articles in both streams, the mean and standard deviation (SD) were calculated and the latter was calculated for the total number of papers and for the period between 2005 and 2014 (the decade for ESD). The results obtained can be seen in Table 1.

Despite the fact that papers related to ESD have increased with respect to those of EE, the SD indicates greater consistency in the publication of papers related to EE. In other words, the EE is still being published and researched in the USA. On the other hand, ESD publications during the end of the decade drastically decreased, and, in turn, research in the USA reached certain stability. Thus, in 2017, there were more publications for EE than for ESD. Discarding the year 2020, there was a growth trend was found for both streams since 2018.

We can see that the decade for ESD had a positive effect on the generation of research on this subject in higher education and that EE was relegated; therefore, we can say that this UNESCO proposal was successful. However, as there was nothing to ensure countries remain aligned in the ESD, the EE appeared to gain strength again.

3.2 Geographical analysis of environmental education and education for sustainable development

The second research question is oriented to the advance of ESD by geographical location. For this analysis, the main division by continents was taken; however, for the American continent, due to the language characteristics and political and development conditions, we decided to divide this region into Latin America and North America, highlighting that Mexico is excluded from the latter region, as it was placed within the Latin American group. On the other hand, Russia, to give greater clarity to the reading of the data, was considered as Europe. A category was included for articles that deal with global issues and do not focus on a specific country or region. In Figure 3, the geographical distribution of the results can be observed.

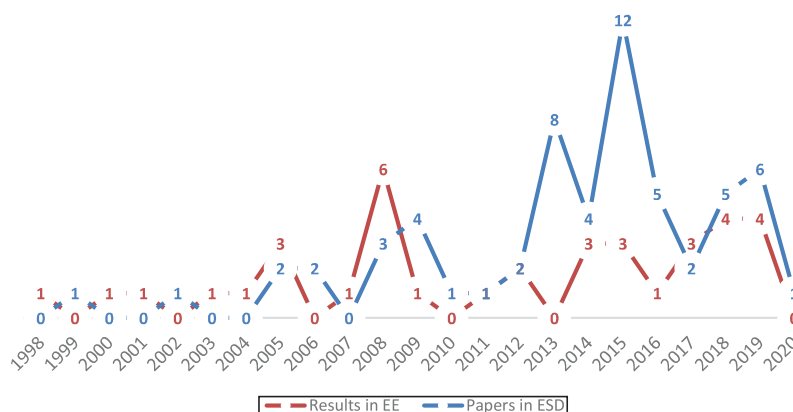


Figure 2. Results in EE and ESD since 1987

3.2.1 *Global.* Global researchers involve two or more regions and, due to their characteristics, their results can be taken or applied at a general level. Table 2 includes the list of articles and their authors, classifying each article in ESD and EE. It was found that five articles were dedicated to the research or analysis of both currents, that is to say, ESD and EE. These articles, although they involve EE in their research, were all focused on the concepts of environmental sustainability and many of these made a union of the concepts as “Environmental Education for sustainable development.” In the case of De Andrade Guerra *et al.* (2018), these authors performed an analysis and found a common background and, for this reason, they decided to take EE and ESD as synonyms. This treatment as synonyms was also used by Kopnina (Kopnina, 2015).

On the other hand, Marouli and Duroy (2019) introduced a synonym for ESD that was defined as Education for Sustainability (EfS). In their study, they conducted an analysis from the question “what pedagogical approaches and tools should EE/EfS adopt to help students think as critical learners and act as empowered citizens with the aim to envision and design sustainable societies?” The answer to the question was made with a comparison between the USA and Greece.

Table 1.
Statistical values of the results obtained between 1987 and 2020

Statistical	Papers in EE	Papers in ESD
<i>n</i> (total)	37	60
%	38%	62%
Mean	2	3
Mean in the decade for ESD (2005–2015)	1.82	3.55
<i>n</i> in the decade for ESD (2005–2015)	20	39
% in the decade for ESD (2005–2015)	34%	66%

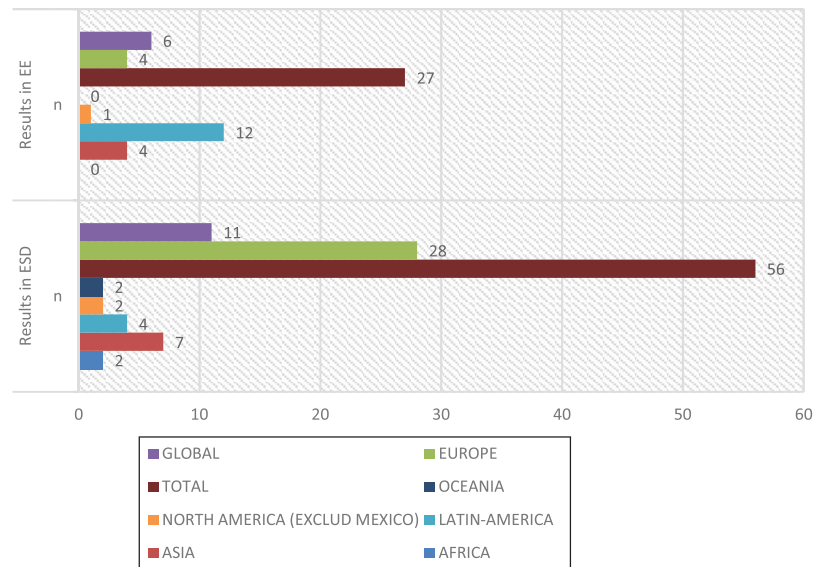


Figure 3.
The ESD and EE results by geographic region

Title	Author	Paper about EE/ESD
Moving toward an ecologically sound society? Starting from green universities and environmental higher education	(Wang <i>et al.</i> , 2013)	ESD
Education for sustainable development: implications for small island developing states	(Crossley and Sprague, 2014)	ESD
The future we want key issues on sustainable development in higher education after Rio and the UN decade of education for sustainable development	(Filho <i>et al.</i> , 2015)	ESD
A study on impact of the UN decade of education for sustainable development on industrial engineering education	(Colombo <i>et al.</i> , 2015)	ESD
Education coupled with entrepreneurial process approach toward sustainable development	(Iyer, 2015)	EE/ESD
Does social justice knowledge matter? Education for sustainable development and student attitudes	(Westerman <i>et al.</i> , 2016)	EE/ESD
Neoliberalism, pluralism and environmental education: The call for radical re-orientation	(Kopnina, 2015)	EE/ESD
Strategies for education for sustainable development – Danish and Australian perspectives	(Egelund Holgaard <i>et al.</i> , 2016a)	ESD
Future sustainability scenarios for universities: moving beyond the United Nations decade of education for sustainable development	(Beynaghi <i>et al.</i> , 2016)	ESD
A proposal of a balanced scorecard for an environmental education program at universities	(de Andrade Guerra <i>et al.</i> , 2018)	EE/ESD
Reflections on the transformative power of environmental education in contemporary societies: experience from two college courses in Greece and the USA	(Marouli and Duroy, 2019)	EE/ESD
Measures to facilitate the scale-up of education for sustainable development in higher education	(McConnon, 2020)	ESD

Table 2.
Articles dealing with
ESD or EE in two or
more continents

3.2.2 Europe. Europe is the continent with more research about ESD and 33.7% of the papers of the total search were dedicated to research on this subject on the continent or in European countries. In [Table 3](#), the articles dedicated to ESD are listed. Likewise, Europe is the region where a greater transition is evident. Leaving aside the EE, in this case, there were no synonyms between ESD and EE, that is, each current and its characteristics were well-defined. In this sense, two research stood out, based on each definition and with a clear differentiation between EE and ESD, which carried out research to determine the perception or reception of these two models.

In Romania, for example, [Ilovan *et al.* \(2019\)](#) dedicated a study with a basic survey to determine the most effective models to apply EE and ESD in the first levels of education (preschool and primary) from the perception of teachers. Prior to this, they had already published a similar study, using the same survey; however, this publication was not found during this search, as it was not stored in the chosen databases.

There are some special cases, such as [Holm *et al.* \(2015\)](#) where a review and analysis of ESD was made in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) and this was compared with China, in terms of the application and promotion policies of this model. In this case, many of the research studies were focused on improving the curricula and determining the status of ESD, while others were devoted to the analysis of the generic application of ESD.

3.2.3 Latin America. It was found that Latin America was the region that continued to research the most in the EE of all the regions, the percentage of the research in ESD was

Title	Author
Environmental education for sustainable development in Russia	(Kasimov <i>et al.</i> , 2005)
Global learning and education for sustainable development	(Brunold, 2005)
A center for excellence in education for sustainable development	(Dyer <i>et al.</i> , 2006)
Implementing the United Nations decade on education for sustainable development in latvian higher education	(Grabovska and Grabowski, 2009)
Embedding education for sustainable development in higher education: a case study examining common challenges and opportunities for undergraduate programs	(Jones <i>et al.</i> , 2008)
Revolutions and second-best solutions: education for sustainable development in higher education	(Cotton <i>et al.</i> , 2009)
Science education and education for citizenship and sustainable development	(Johnston, 2011)
An understanding of sustainability and education for sustainable development among German student teachers and trainee teachers of chemistry	(Burmeister and Eilks, 2013)
Education for sustainable development: methodology and application within a construction course	(Soria <i>et al.</i> , 2013a)
Integration of education for sustainable development in the mechanical engineering curriculum	(Enelund <i>et al.</i> , 2013)
Developing and piloting a baselining tool for education for sustainable development and global citizenship (ESDGC) in Welsh higher education	(Glover <i>et al.</i> , 2013)
Education for sustainable development in higher education: state-of-the-art, barriers and challenges	(Fernández Sánchez <i>et al.</i> , 2014)
Education for sustainable development and quality assurance in universities in China and the Nordic countries: a comparative study	(Holm <i>et al.</i> , 2015)
Education for sustainable development through e-learning in higher education: experiences from Portugal	(Azeiteiro <i>et al.</i> , 2015)
Education for sustainable development in higher education: evaluating coherence between theory and praxis	(Amador <i>et al.</i> , 2015a)
(Education for) Sustainable development in geography education: review and outlook from a perspective of germany	(Sprenger and Nienaber, 2018)
Master's program module "Environmental Issues–Decision Making Experience" as precondition for implementation of education for sustainable development for professional training of teachers	(Stepanskaya <i>et al.</i> , 2016)
Higher education in the sustainable development goals framework	(Owens, 2017)
Catalysing change in higher education for sustainable development: a review of professional development initiatives for university educators	(Mulà <i>et al.</i> , 2017a)
Improving engineering education for sustainable development using concept maps and multivariate data analysis	(Svanström <i>et al.</i> , 2018)
Training ESD change agents through geography: designing the curriculum of a Master's Program with emphasis on education for sustainable development (ESD)	(Bagoly-Simó <i>et al.</i> , 2018)
Rating and rewarding higher education for sustainable development research within the marketized higher education context: experiences from English universities	(Bessant and Robinson, 2019)
Electronic mobile devices in environmental education (EE) and education for sustainable development (ESD) – evaluation of concepts and potentials	(Bleck <i>et al.</i> , 2012)
Rethinking higher education for sustainable development in Serbia: An assessment of Copernicus charter principles in current higher education practices	(Milutinović and Nikolić, 2014)
Education for sustainable development (ESD): exploring anthropocentric–egocentric values in children through vignettes	(Kopnina, 2014)
Environmental behaviors in initial professional development and their relationship with university education	(Fernández-Manzanal <i>et al.</i> , 2015)
Environmental education and education for sustainable development in Romania. Teachers perceptions and recommendations	(ilovan <i>et al.</i> , 2019)

Table 3.
Papers about ESD
published in Europe

barely 4.8%, which corresponds to four articles. Table 4 shows the studies that were found. In contrast, publications regarding EE represented the highest percentage, with 14.5% of all publications. This corresponds to 37.5% of the articles published in EE, that is, 12 articles.

The case of ESD for this region appears to be incipient. There are cases, such as Lopez *et al.* (2018), who presented approaches to ESD and recommended to move from EE to ESD in Colombia. Ecuador stands out in this region in the ESD because it has two publications, one belongs to (Barth and Rieckmann, 2012), focused on the inclusion of ESD in the academic staff of a university in that country. Years later, Perello-Marín *et al.* (2018), presented a proposal to improve and include ESD in higher education programs; however, they mentioned the current low level of this research in Latin America and that Ecuador had a propitious context to explore and further research.

3.2.4 Asia. The articles for Asia were also higher in ESD with 8.46% of the total, compared to 4.8% of the papers from the USA. In this continent, the publications of ESD were constant in the period of the decade for ESD; however, since 2017, there were publications again on EE and no publications on ESD. The last two publications on EE were from (Liu, 2018; Yan *et al.*, 2019). In both articles, they took an involuntary distance from the

Title	Reference	EE/ ESD
Education for sustainable development: the engineer of the twenty-first century	(Velazquez <i>et al.</i> , 1999)	ESD
Modelo didáctico para la enseñanza de la educación ambiental en la educación superior venezolana	(Romero and Nick, 2007)	EE
Educación superior y cultura ambiental en el sureste de México	(Sosa, 2010)	EE
Formulación de las políticas de educación ambiental: en el contexto del desarrollo endógeno, sustentable y humano un modelo para las instituciones de educación superior en Venezuela	(Díaz <i>et al.</i> , 2008)	EE
Environmental education in higher education institutions in bolivar state, Venezuela	(Valeron, 2008)	EE
La educación ambiental en el nivel educativo superior de Manizales	(Sepulveda, 2012)	EE
Academic staff development as a catalyst for curriculum change toward education for sustainable development: an output perspective	(Barth and Rieckmann, 2012)	ESD
La formación ambiental en la educación superior: una revisión necesaria	(Molano Niño and Herrera Romero, 2014)	EE
El efecto del currículo oculto de educación ambiental en estudiantes de educación superior	(Colón, 2016)	EE
La educación ambiental en las instituciones de educación superior públicas acreditadas en Colombia	(Berdugo Silva and Montaña Renuma, 2017)	EE
Pedagogía ambiental y didáctica ambiental: tendencias en la educación superior	(Tovar-Gálvez, 2017)	EE
El compromiso ambiental de instituciones de educación superior en Colombia	(Callejas Restrepo <i>et al.</i> , 2019)	EE
Enhancing education for sustainable development in environmental university programmers: a co-creation approach	(Perello-Marín <i>et al.</i> , 2018)	ESD
Educación para el desarrollo sostenible: acercamientos desde una perspectiva colombiana	(María <i>et al.</i> , 2018)	EE
Education for sustainable development in the context of higher education in Bolivia. Perceptions of university professors	(Litzner Ordóñez and Rieß, 2019)	ESD
The lack of environmental education in the training of environmental engineers in Colombia	(Castellanos <i>et al.</i> , 2020)	EE

Table 4.
Papers in Latin
America about ESD
and EE

precepts of sustainable development and leaned toward the precepts and objectives of EE. In Table 5, the results of this region are presented.

3.2.5 *Africa and Oceania.* Africa and Oceania represent a particular case, which had two articles for ESD and none for EE. One of the studies (Ekpiken and Ukpabio, 2015) developed in Nigeria sought to measure the empowerment capacity of young people toward environmental attitudes focused on sustainable development. The same topic was considered by Richter and De Sousa (2019). The results can be applied in a general and global way, as they concluded with suggestions for how ESD can be implemented in an education faculty from an analysis of the entire educational spectrum from the primary to doctorate level in South Africa.

Regarding Oceania, one of the articles published by Sherren (2008), describes the degree of inclusion of EE, considered as synonymous of ESD, in undergraduate and postgraduate courses in Australia. In this case, they took ESD as EfS as in the cases we analyzed in North America. On the other hand, Shephard et al. (2015), in a study for New Zealand, reviewed the difficulties of including ESD in higher education. This was an interesting analysis of the affective attributes of students.

3.2.6 *North America.* One of the characteristics observed in the publications of North America, excluding Mexico, was the absence of recent publications in addition to having a fairly low number compared to the rest of the regions. In this case, two publications for ESD were found, one from the USA (Vann et al., 2006) and another from Canada (Sims and Falkenberg, 2013). There was only one article regarding EE (Hyde and Karney, 2001). The most recent publication was from 2013, from Sims and Falkenberg (2013). The authors

Title	Author	Paper about EE or ESD?
Interdisciplinary approach to environmental education	(Semerjian et al., 2004)	EE
Teaching for sustainable development in higher education institutions: University of Jordan as a case study	(Hola et al., 2009)	ESD
A perspective on education for sustainable development: historical development of environmental education in Indonesia	(Nomura, 2009)	ESD
Education for sustainable development: liberation or indoctrination? An assessment of faculty members' attitudes and classroom practices	(Qablan et al., 2009)	ESD
Innovative approaches for promoting environmental education in India	(Gupta et al., 2011)	EE
A critical assessment of the higher education for sustainable development from students' perspectives – a Chinese study	(Yuan and Zuo, 2013)	ESD
A vision on the role of environmental higher education contributing to the sustainable development in Malaysia	(Foo, 2013)	ESD
Education for sustainable development and environmental ethics	(Nasibulina, 2015)	ESD
Analyzing key debates in education and sustainable development in relation to ESD practice in VietNam	(Balls, 2016)	ESD
Environmental education through documentaries: assessing learning outcomes of a general environmental studies course	(Liu, 2018)	EE
A collaborative environmental education pattern of deepening the integration of production and education based on application-oriented undergraduate teaching: a case study in civil engineering (major of Beibu Gulf University)	(Yan et al., 2019)	EE

Table 5.
Papers in Asia on ESD and EE

reviewed the inclusion of ESD in educational colleges in Canada. They provided an overview of the integration of ESD in the most important Canadian universities and presented the successes and challenges that this model faces.

3.3 Inclusion of education for sustainable development in the teaching of engineering

Of the total selected articles, 84% were dedicated exclusively to higher education, the remaining articles involved other education niches, such as K–12 with higher education. In total, 23% of the papers partially included ESD with engineering.

Only 8% of the total papers were dedicated exclusively to the relationship between ESD and engineering education, corresponding to seven papers, from only three regions: Europe, Latin America and two papers that studied ESD and engineering at a worldwide level. A summary of the geographical distribution of papers about engineering education can be seen in [Table 6](#).

The oldest publication that addressed ESD in engineering education was entitled “Education for sustainable development: The engineer of the 21st century” whose authors were [Velazquez et al. \(1999\)](#). In this, the authors for industrial engineering defined that this educational model creates a scenario that transforms the training of pollution control engineering to seek alternates for cleaner production in accordance with the principles of sustainable development.

After seven years with no publication about ESD in engineering, [Dyer et al. \(2006\)](#) published a paper, in this publication, they provided an overview of 74 Centers for Excellence in Teaching and Learning (CETL) in the UK and this was tangentially linked to engineering. This is because they sought to increase ESD in general in all universities, which implies the teaching of ESD in engineering. [Table 7](#), shows the publications that partially involve ESD in engineering.

Seven publications were found in this systematic review that are exclusively dedicated to study and analyze ESD within engineering. [Velazquez et al. \(1999\)](#) were the first to tackle ESD in engineering in our search. The article by [Soria et al. \(2013a, 2013b\)](#) embodies a series of actions with the aim of integrating ESD in a transversal way to all undergraduate degrees, taking, as an example, a study carried out in industrial engineering. The authors showed a replicable methodology, where development can be integrated into the competencies that are addressed during a subject.

On the other hand, [Enelund et al. \(2013\)](#) presented a case study applied to the Mechanical Engineering Master Degree at the Chalmers University of Technology in Australia. Through an analysis of the curriculum of this program and the competencies of the

Main topic	n	(%)
<i>Partially include ESD in Engineering</i>	19	23
Asia	3	4
Europa	10	12
Global	3	4
Latin-America	1	1
Oceania	2	2
<i>Include ESD in Engineering</i>	7	8
Europa	3	4
Global	2	2
Latin-America	2	2
Total	33	40

Table 6.
ESD Publications
about engineering
education

Table 7.
Publications that
partially involve ESD
in engineering
teaching

Title	Authors
A centre for excellence in education for sustainable development	(Dyer <i>et al.</i> , 2006)
Implementing the United Nations decade on education for sustainable development in Latvian higher education	(Dyer <i>et al.</i> , 2006)
Embedding education for sustainable development in higher education: a case study examining common challenges and opportunities for undergraduate programs	(Jones <i>et al.</i> , 2008)
Revolutions and second-best solutions: education for sustainable development in higher education	(Cotton <i>et al.</i> , 2009)
A perspective on education for sustainable development: historical development of environmental education in Indonesia	(Cotton <i>et al.</i> , 2009)
Education for sustainable development: liberation or indoctrination? An assessment of faculty members' attitudes and classroom practices	(Qablan <i>et al.</i> , 2009)
A critical assessment of the higher education for sustainable development from students' perspectives – a Chinese study	(Yuan and Zuo, 2013)
Seeking learning outcomes appropriate for “Education for Sustainable Development” and for higher education	(Shephard <i>et al.</i> , 2015)
Education for sustainable development and quality assurance in universities in China and the Nordic countries: a comparative study	(Holm <i>et al.</i> , 2015)
Education coupled with entrepreneurial process approach toward sustainable development	(Iyer, 2015)
Education for sustainable development through e-learning in higher education: experiences from Portugal	(Azeiteiro <i>et al.</i> , 2015)
Education for sustainable development in higher education: evaluating coherence between theory and praxis	(Amador <i>et al.</i> , 2015b)
Catalysing change in higher education for sustainable development: A review of professional development initiatives for university educators	(Mulà <i>et al.</i> , 2017b)
Education for sustainable development in the context of higher education in Bolivia. Perceptions of university professors	(Litzner Ordóñez and Rieß, 2019)
High level education on integrated water resources management for sustainable development	(Grau <i>et al.</i> , 2019)
Measures to facilitate the scale-up of education for sustainable development in higher education	(McConnon, 2020)
Rethinking higher education for sustainable development in Serbia: An assessment of Copernicus charter principles in current higher education practices	(Milutinović and Nikolić, 2014)
Environmental behaviors in initial professional development and their relationship with university education	(Fernández-Manzanal <i>et al.</i> , 2015)

graduates, they made a proposal for the transformation of the Master Degree and included ESD. They also applied surveys to the students to identify the degree of acceptance of the ESD. The results of this research encourage the transformation of study plans to integrate sustainability and make this a goal within the subjects.

Colombo *et al.* (2015) conducted a non-systematic bibliographic review of the proceedings of two conferences and papers from five journals, taking these as a reference for the UNESCO ESD. The purpose of this research was to review and observe the inclusion of sustainability in engineering courses, particularly in Organization Engineering Undergraduate Degree. Solutions to integrate sustainability in engineering from these authors included the reform of specific curricula, programs or courses on sustainability and to integrate disciplines other than engineering with a sustainability approach. One of the most comprehensive articles addressing ESD is that of (Egelund Holgaard *et al.*, 2016a). In this research, a study was made on the strategies of this model in engineering with a comparison between Australia and Denmark. In this same study, they coined the acronym

EESD for education in engineering for sustainable development. The article indicates that there are many strategies to strengthen ESD within engineering education and, therefore, it is necessary to establish a conceptual framework to characterize the ESD activities within engineering education. On the Danish side, it is evident that, although ESD is known in the academic field, most of the transformations occur due to initiatives of academicians in universities driven by a personal commitment to research projects.

As there was very little support from the government for the inclusion of sustainability in higher education institutions, the Australian case is not very different from Denmark where the government did not play an important role. Within the conceptual framework, the authors listed the actors and facilitators necessary to include ESD in universities and especially in engineering and they also proposed five steps to understand the activities and facilitators of ESD.

The majority of the articles focused on improving the inclusion of ESD in the teaching of higher education programs. [Egelund Holgaard et al. \(2016a, 2016b\)](#) proposed a co-creation process to achieve this improvement. To do this, they conducted a survey between students from programs related to the environment in 12 universities in Ecuador, including environmental engineering programs. In the research, they proposed a co-creation model based on the participation of students and other satellite actors that ultimately seek positive impacts on satisfaction and trust around sustainability.

The results were very satisfactory after the mathematical validations and present a replicable model where sustainability can have a greater impact on those involved. Finally, [Svanström et al. \(2018\)](#) presented a research-based master's program in engineering education. In this program, they carried out activities around concept maps and multivariate data analysis with the students. This method seeks to create a greater apprehension of ESD concepts and of the students' competencies.

As can be seen, there are different factors that characterize ESD research in engineering. Most studies were performed around industrial engineering and there were studies on how to include sustainability in the curricula. However, the small number of publications is preponderant.

4. Discussion

The educational field is extremely diverse in regard to ESD and EE. After a detailed review, the results of this systematic review showed similarities and differences that characterize each region of the planet. ESD is increasingly prevalent in education in all its ranges and especially in higher education ([Radinger-Peer and Pflitsch, 2017](#)). A clear limitation is the number of publications on the design and review of study plans that refer to ESD in ensuring that universities are a catalyst for sustainable development and that those trained in these institutions are important actors in achieving this goal ([Wals, 2014](#)).

Universities play an important role in their engagement in SDG ([El-Jardali et al., 2018](#)). This seeks not only a subjective "quality education" but also for universities to leverage the improvements of the ESD model, leaving aside EE ([Acosta Castellanos et al., 2020](#); [Aguilar, 2018](#)). This does not mean that EE is itself outdated or that it does not serve the purposes of protecting the environment; however, among these two currents (which are the most prominent) ESD is the most advantageous for countries and nations to achieve sustainable development.

UNESCO has invested efforts into this and this has been received in different ways ([Nousheen et al., 2020](#)). Europe clearly echoes this call and performed more research than any other region on this methodology. Africa was the region with the least research. Regarding this, the factor could be economic, as an investment in education for Europe is in

an average of 5.0% of the GDP per year (Zoran, 2015), while for Africa, this is an average of 3% of the GDP per year, excluding high-income countries, such as Saudi Arabia and the United Arab Emirates (Aguado, 2012).

On the contrary and far from this statement, the results showed that the USA and Canada develop research related to ESD in amounts similar to Africa; therefore, the reason is not only the economic factor. There is a relationship between Africa, Canada and the USA, which is a lack of environmental policies that support and promote sustainable development (Takeuchi and Aginam, 2011; Yanarella, 1999).

In this sense, regardless of the country or region, the non-existence of support from government institutions and their policies means that universities do not focus their objective on research or engaging in ESD (Vargas *et al.*, 2019). The efforts that could be seen were personal or individual researchers focused on ESD, but not institutional purposes (Egelund Holgaard *et al.*, 2016b).

Sustainable development can be achieved through the responsible use of renewable natural resources and their preservation for the enjoyment of future generations; however, university institutions appear to not contribute to this purpose and, therefore, higher education for sustainable development is lagging (Cotton *et al.*, 2009). Due to this and the fact that ESD is not widely known in higher education, researchers encounter great obstacles to finance their research and producing new knowledge (Bessant and Robinson, 2019).

A particular case is Latin America. This region is almost homogeneous research and deepening in EE and this methodology has features that involve people's behaviors toward the protection and use of natural resources (González-Gaudiano, 2016). This is far from the objective of achieving sustainable development and it appears that this region has stagnated in time and will go further from the objectives that all the countries of this region committed to fulfill the 2030 agenda. The answer to the question that arose from the results of this research, why Latin America is still anchored in EE may be complex.

On the one hand, this current favors political movements and populism (Hursh *et al.*, 2015; Kopnina, 2015; Stevenson, 2007), something common in this region with political and state instability. Coupled with this is a lack of commitment by states to achieve sustainable development, including a lack of policies for sustainable development and low investments in education and science (Briggs *et al.*, 2018; Ferguson, 2020). On the other hand, the research carried out in this region reinforces an apparent exploitative and imperialist vision coming from within the ESD. In this review, several statements, such as that made by González-Gaudiano (2016) were found; "Ultimately, ESD perpetuates a system that produces social inequality (poverty) and environmental destruction."

Without a doubt, Europe is the region that contributed with the most effort in research and deepening the research on ESD. This research was not being conducted on EE, that is, this issue has already been overcome. Some particularities arose in this research, especially in North America, where EE and ESD are often confused or merged as a single current. This can generate confusion for a reader as, from an epistemological and historical point of view, they are different, although they cross in some respects. Engineering plays an important role in the search for sustainable development as engineers develop and apply new technologies; therefore, these technologies must be in accordance with the needs of not only people but also the environment, which is in crisis.

The clearest answer to this need is to train engineers who are capable of understanding the problems not only in their area but also in their surroundings in environmental terms. These are new engineers with all the capabilities of their predecessors regarding the technical aspects but with more holistic thinking. To achieve this fusion, it is necessary to

include ESD in the curricula and in the training of engineers. In our research, this was clearly identified as a flaw.

As there are few research that involves ESD in engineering, interesting cases, such as that of (Velazquez *et al.*, 1999), have been paving the way forward for two decades. The lack of response from engineering companies in involving ESD in the curricula has to do precisely with what was mentioned at the beginning of this discussion section and that is that there are no clear guidelines given to universities and, in this case, engineering programs regarding a clear path to make ESD an important component of engineering education. If this is achieved, it can give way to curricular transformations where environmental sustainability is included not only as content in the curricula but also as something transversal to achieve changes that really impact the planet.

5. Conclusions

Within this research, the authors found that ESD is not a mature and generalized model. It is evident that some regions of the planet are investigating and advancing more in EE, as is practically the entire American continent. This is beneficial for academic diversity and the promotion of multiculturalism, something that both ESD and EE share in their foundations. In this same sense, it was possible to show that the decade for ESD proposed by UNESCO had a great effect on the amount of research on this subject, but after this event, the number of ESD research fell. Europe is the continent that investigates the most in ESD and leads the number of investigations worldwide in this regard.

We evidenced a lack in the amount of research in the databases analyzed regarding the analysis or experimentation of the inclusion of EE or ESD within engineering curricula. It is necessary for universities and engineering faculties to promote experimentation and the publication of results in this regard, with this being able to generate a nucleus of validated knowledge capable of improving the curricula of engineering programs.

It can be observed that both ESD and EE have advantages and disadvantages that must be analyzed. Among the disadvantages that are observed more frequently in ESD, is the academic and cultural homogenization and a lack of clarity regarding the position of the ESD versus consumer society. For its part against EE, the most constant criticism is its politicization and the confrontation it has with the promotion of conservationism, and, in turn, the promotion of SD. These disadvantages or criticisms have a positive side and it is the strong research and analysis that is seen in the publications regarding the discussion that is had to seek to close these gaps or problems that are evidenced by ESD or EE.

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