TESIS DOCTORAL

POR COMPENDIO DE PUBLICACIONES

DOCTORADO EN FORMACIÓN EN LA SOCIEDAD DEL CONOCIMIENTO

ANÁLISIS DE LA EDUCACIÓN AMBIENTAL Y LA EDUCACIÓN PARA EL DESARROLLO SOSTENIBLE EN LA ENSEÑANZA DE LA INGENIERÍA

Doctorando:

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Directora:

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2023

A mi esposa, mis padres, a mis hermanas y hermano, mis sobrinos y negrito.

PROGRAMA DE DOCTORADO FORMACIÓN EN LA SOCIEDAD DEL CONOCIMIENTO

AGRADECIMIENTOS

Hay tantas personas a las que debo agradecer este logró tan gratificante en lo personal. Sin lugar a dudas tengo una inmensa gratitud a Araceli Queiruga Dios, mi directora, por confiar en mí desde que me postulé al doctorado, gracias Araceli, por tus enseñanzas, apoyo y guía durante este proceso. Gracias a la Universidad de Salamanca, su grandeza no es en años, no es en número de estudiantes, es en su humanidad, entrega y apoyo de cada uno de sus trabajadores. Al doctorado y su director, al Dr. Francisco García Peñalvo. A la Universidad Santo Tomás por su apoyo, especialmente a los Frailes Dominicos.

En lo personal, sin duda debo agradecer a mi amada esposa Carolina, a mis padres por su amor, a mis hermanos por su ejemplo, a mis sobrinos por su cariño y a mi fiel compañero de estudio negrito.

RESUMEN

Los modelos de educación en temas ambientales predominantes en el mundo son la educación ambiental (EA) y la educación para el desarrollo sostenible (EDS). La EA se distingue especialmente por el interés en la protección y conservación de los recursos naturales. Este rasgo ha hecho que sea un buen pendón para los discursos políticos y demagógicos, especialmente en lugares como Latinoamérica. Por su parte, la EDS es más reciente, su fuerza como modelo de educación comenzó en la primera década del siglo XX, una de sus características es que es un modelo antropocéntrico e impulsador del desarrollo económico como principio para lograr el desarrollo social y el equilibro ambiental. La educación superior, y en especial las ingenierías, no son ajenas a la disputa por la selección del modelo que debe ser incluido dentro de sus enseñanzas.

Con esta tesis doctoral se buscó establecer el grado de conocimiento y aplicabilidad de la EA y la EDS en Latinoamérica y con un especial énfasis en Colombia. Se logró encontrar que, a nivel global, Latinoamérica es una de las regiones con menos conocimiento de la EDS y con un fuerte arraigo de la EA, en comparación con otras regiones como Europa, donde predomina la EDS. Así mismo, se identificaron los rasgos que caracterizan la EA en Latinoamérica, en la enseñanza de las ingenierías, así como la falta de conocimiento de la EDS por parte de los profesores y estudiantes de dichas titulaciones. Finalmente, se propuso una estrategia mediadora entre la EA y la EDS con la finalidad de incluirlas dentro de los planes de estudio de las ingenierías, mediante la propuesta de una nueva asignatura. En este

sentido, se evidenciaron las ventajas y desventajas de esta metodología a partir de su implementación en el programa de ingeniería ambiental de la Universidad Santo Tomás en Colombia.

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1. PRESENTACIÓN DE LA TESIS DOCTORAL

Esta tesis se enmarca en las disposiciones del RD 99/2011, de 28 de enero (modificado por Real Decreto 534/2013, de 12 de julio), por el cual se regulan las enseñanzas oficiales de doctorado. La Comisión de Doctorado y Posgrado de la Universidad de Salamanca establece el procedimiento para la presentación de la tesis doctoral en el formato de compendio de artículos/publicaciones. Así mismo, el programa de doctorado en Formación en la Sociedad del Conocimiento establece internamente un reglamento donde se dictan las directrices para este tipo de formato de tesis doctoral dentro del programa, establecido por la comisión académica el 30 de enero de 2018.

Las publicaciones presentadas en esta tesis cumplen con los requisitos de calidad de indexación en Journal Citation Report (JCR) y no en cualquier cuartil inferior a Q1 de Scopus, así como con las demás exigencias estipuladas en el reglamento general del programa referente a las tesis doctorales en formato de compendio de artículos/publicaciones.

Se incluye a continuación el listado de artículos publicados, junto con sus datos de referencia e índices de calidad:

1.1. Artículo 1

- Título: Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America.

- Autores: Acosta Castellanos, P. M., Queiruga-Dios, A., Encinas, A. H., & Acosta, L. C.
- Nombre de revista: Sustainability
- Volumen: 12
- Páginas: 1-14
- Año de publicación: 2020
- DOI: 10.3390/su12187239
- Editorial: MDPI
- ISSN: 2071-1050
- Proceso de publicación:
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    - ✓ Revisado: 21de agosto de 2020
    - ✓ Disponible online: 4 de septiembre de 2020
- Revista indexada en Web of Science (2020):
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    - ✓ Categoría de la revista: Environmental Studies
    - ✓ Posición de la revista en esta categoría: 59/125
    - ✓ Cuartil: Q2
- Revista indexada en Scopus (2020):
    - ✓ Impacto de citación: 3.9

- ✓ Categoría de la revista: Environmental Science (miscellaneous).
- ✓ Posición de la revista en esta categoría: 18/104
- ✓ Cuartil: Q1

1.2. Artículo 2

- Título: From environmental education to education for sustainable development in higher education: a systematic review.
- Autores: Acosta Castellanos, P. M., & Queiruga-Dios, A.
- Nombre de revista: International Journal of Sustainability in Higher Education
- Volumen: 23
- Páginas: 622–644
- Año de publicación: 2020
- DOI: 10.1108/IJSHE-04-2021-0167
- Editorial: Emerald Group Holdings Ltd.
- ISSN: 1467-6370
- Proceso de publicación:
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  - ✓ Revisado: 28 de junio de 2021
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- Revista indexada en Web of Science (2021):
  - ✓ Factor de impacto: 4.12

- ✓ Categoría de la revista: Education & Educational Research
- ✓ Posición de la revista en esta categoría: 44/270
- ✓ Cuartil: Q1

- Revista indexada en Scopus (2021):
  - ✓ Impacto de citación: 5.6
  - ✓ Categoría de la revista: Social Sciences; Education
  - ✓ Posición de la revista en esta categoría: 107/1406
  - ✓ Cuartil: Q1

1.3. Artículo 3

- Título: Education for Sustainable Development (ESD): an example of curricular inclusion in environmental engineering in Colombia.
- Autores: Acosta Castellanos, P. M., & Queiruga-Dios, A.
- Nombre de revista: Sustainability
- Volumen: 16
- Páginas: 1-21
- Año de publicación: 2022
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- ✓ Disponible online: 10 de agosto de 2022

- Revista indexada en Web of Science (2021):
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- Revista indexada en Scopus: (2021).
  - ✓ Impacto de citación: 5.0
  - ✓ Categoría de la revista: Environmental Science (miscellaneous).
  - ✓ Posición de la revista en esta categoría: 20/133
  - ✓ Cuartil: Q1

1.4. Nombres y afiliación de los autores de las publicaciones principales

Araceli Queiruga Dios, Universidad de Salamanca, Escuela Técnica Superior de Ingeniería Industrial, Departamento de Matemática Aplicada.

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Libia Cristina Acosta Castellanos, Universidad Libre de Colombia.

1.5. Autorización de presentación de la Tesis

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Salamanca, 30 de diciembre de 2022

Dña. Araceli Queiruga Dios, Profesora Titular de Universidad del Departamento Matemática Aplicada de la Escuela Técnica Superior de Ingeniería Industrial de la Universidad de Salamanca y directora de la tesis doctoral de D. Pedro Mauricio Acosta Castellanos, titulada "Análisis de la educación ambiental y la educación para el desarrollo sostenible en la enseñanza de la ingeniería",

AUTORIZA

A D. Pedro Mauricio Acosta Castellanos a presentar y defender su tesis doctoral en la modalidad de compendio de artículos publicados en revistas internacionales indexadas en el WoS-JCR.

Firmado digitalmente por QUEIRUGA DIOS, MARIA ARACELI (AUTENTICACIÓN)
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Fdo.: Araceli Queiruga Dios

1.6. Declaración de autoría

D. Pedro Mauricio Acosta Castellanos presenta la tesis doctoral titulada “Análisis de la educación ambiental y la educación para el desarrollo sostenible en la enseñanza de la ingeniería” para optar al grado de Doctor por la Universidad de Salamanca, y declara que esta tesis ha sido realizada bajo la dirección de la Dra. Araceli Queiruga Dios. Así mismo declara que es autor principal de la investigación que se recoge en los artículos presentados.

En Salamanca, 24 de enero de 2023.

El doctorando,

Pedro Mauricio Acosta Castellanos

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HAGO CONSTAR:

Que soy COAUTOR/A de los siguientes trabajos:

Acosta Castellanos, P. M., Queiruga-Dios, A., Hernández Encinas, A., & Acosta, L. C. (2020). Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America. Sustainability, 12(18), 7239. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su12187239

Y MANIFIESTO QUE:

☑ Como COAUTOR/A NO DOCTOR/A del trabajo del doctorando Pedro Mauricio Acosta Castellanos expreso mi RENUNCIA a presentar el artículo como parte de otra Tesis Doctoral.

☑ Como COAUTOR/A del trabajo del doctorando Pedro Mauricio Acosta Castellanos acepto que dicho trabajo sea presentado como parte de su Tesis Doctoral y declaro que el doctorando es el autor principal de la investigación recogida en estos trabajos.

Salamanca a 3 de noviembre de 2022

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Salamanca a 3 de noviembre de 2021

Fdo: Libia Cristina Acosta Castellanos

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2. INTRODUCCIÓN

En Colombia y Latinoamérica, la educación ambiental ha estado presente en la formación académica desde la última mitad del siglo XX, y es la única metodología que busca enseñar a los estudiantes, y a la sociedad en general, los problemas a los que se enfrenta el planeta en términos ambientales, con unas características que, en algunos casos, no concuerdan con las tendencias económicas globales. La EA está presente, mayoritariamente, en las etapas de primaria y secundaria y, de manera muy poco visible, en los currículos de educación superior.

A finales del siglo XX surgió la educación para el desarrollo sostenible (EDS), que busca formar en el desarrollo sostenible (DS), como la base para remediar los problemas ambientales, a la vez que permita un futuro con mejores garantías sociales y económicas para los seres humanos. La EDS, en contraste con la EA, muy poco conocida en Latinoamérica, aparece muy pocas veces en los currículos de primaria, secundaria o educación superior, y encaja mejor que la EA en esos niveles educativos, dado su enfoque global de crecimiento económico y mejora social, esta misma característica dificulta a la EDS ganar los espacios en los que la EA está presente.

No es común que en las universidades se traten temas ambientales fuera de los contextos que tienen una vinculación directa con el área ambiental. Las ingenierías son un claro ejemplo de ello, pues no es usual que los programas de estas disciplinas incluyan, dentro de sus currículos, la EA o la EDS. Sin embargo, se esperaría que, en la ingeniería ambiental, que es

la más relacionada con aspectos ambientales, existieran fuertes evidencias de alguna de las dos corrientes.

En esta investigación se ha conseguido evidenciar que, en contra de lo que sería esperable, la integración de la EA en el currículo de ingeniería ambiental en Colombia y Latinoamérica no se ha generalizado. Aunque existen evidencias de casos en los que sobresale la inclusión de la EA en los currículos, estos casos son escasos y no son representativos. Por otra parte, se analizó igualmente la integración de la EDS en los currículos, en diferentes regiones del planeta y con especial énfasis en Latinoamérica, donde se llegó a la conclusión de que existe un vacío del conocimiento sobre la EDS comparado con la EA. Esto presenta una preocupación en los compromisos mundiales para lograr los objetivos de desarrollo sostenible (ODS), ya que la EDS fue propuesta como el pilar fundamental para lograr su cumplimiento.

Como consecuencia de lo mencionado anteriormente, se hace necesario generar alternativas para la vinculación de la EDS con los currículos, ya sea para evaluar su pertinencia o para que, definitivamente, sea implementada. En esta investigación se propone un modelo de implementación de la EDS basado en la evaluación curricular, asistido con encuestas y revisiones sistemáticas, que permitió identificar los vacíos y posibilidades de mejora. Para definir este modelo se utilizó un programa de grado en ingeniería ambiental en una universidad en Colombia, lo que ha supuesto un avance en la inclusión de la EDS en los currículos de educación superior y especialmente en las ingenierías.

2.1. Hipótesis

Esta investigación busca establecer si los modelos de formación más conocidos en términos ambientales, la EA y la EDS, forman parte de los currículos en la educación universitaria, específicamente en las ingenierías. Se tomó como referencia la titulación de grado en ingeniería ambiental, de la Universidad Santo Tomás de Colombia, y se evaluó la presencia de los dos enfoques de formación, para posteriormente ampliarlo a las ingenierías en general. Dado que el grado en ingeniería ambiental se centra en temas relacionados con el medio ambiente, podría servir de punto de partida para su aplicación en otras ingenierías. Con la evaluación realizada durante esta tesis, se buscó verificar los currículos de las ingenierías, revisando la existencia de asignaturas o temarios que incluyeran alguna de estas dos corrientes de formación. Así mismo, resultaba adecuado determinar el nivel de conocimiento, importancia y utilidad profesional que tenían o pudieran tener la EA y la EDS. Finalmente, se implementó la EDS dentro de un currículo para evaluar su efectividad y aceptación por parte de los actores académicos, tanto estudiantes como profesores. De esta forma se ha podido comprobar que la EDS responde a los retos ambientales contemporáneos y es adecuada para la formación en ingeniería. Uno de los motivos para incluir la EDS en las ingenierías es la contribución, a la industria y la economía, que supone la aplicación de los adelantos en ingeniería (Klimska, 2021).

2.2. Objetivos

2.2.1. Objetivo General

El objetivo general de esta tesis es el de analizar la aplicación y el impacto de los dos enfoques educativos de sostenibilidad ambiental más utilizados, la EA y la EDS, en las enseñanzas de ingeniería.

2.2.2. Objetivos Específicos

El objetivo general propuesto incluye los siguientes objetivos específicos:

- ✓ Evaluar los planes de estudio de las ingenierías para evidenciar la inclusión de la EA y la EDS, partiendo de los títulos de grado en ingeniería ambiental.
- ✓ Determinar el nivel de conocimiento de estudiantes, docentes y egresados de los dos modelos de formación en sostenibilidad ambiental.
- ✓ Implementar la EDS dentro de la enseñanza de un programa de grado de ingeniería y evaluar su efectividad.

2.3. Metodología

La metodología utilizada en esta investigación se basa en la búsqueda de evidencias sobre la aplicación y relevancia que tienen, en la formación de los ingenieros, las dos corrientes mencionadas, la EA y la EDS. Para encontrar dichas evidencias se recogió la información de los currículos de los planes de estudio de los programas de grados en ingeniería en Colombia, se revisaron las asignaturas y, además, se comprobó mediante la utilización de encuestas a docentes y estudiantes. Posteriormente se realizó un análisis de resultados para verificar si la educación universitaria en las ingenierías está relacionada o está en línea con los ODS propuestos por la ONU, lo que fue posible mediante experimentación curricular. Es decir, se incluyó una asignatura fundamentada en los conceptos, teorías y prácticas de la EDS en un grado de ingeniería ambiental de Colombia.

Por otra parte, se evaluó el grado en ingeniería ambiental de varias universidades de Colombia, debido a que es relativamente nuevo en el país y que, por su fundamento ambiental, se esperaría que tuviera mayor inclusión de la EA o la EDS (Ramos Torres, 2021). Este análisis se utilizó para establecer un marco de referencia que permitiera realizar la evaluación curricular. Es importante mencionar que, para los procesos de encuestas realizados durante esta investigación doctoral, se tuvieron en cuenta las normas y códigos de ética para diferentes procesos, como encuestas, se utilizó como referencia para ello la *"Guía ética para la investigación educativa*" de la Asociación Británica de Investigación Educativa,

en la cual se plasman los principios éticos en investigaciones educativas (British Educational Research Association, 2018).

2.3.1. Revisión de los currículos

Como es bien sabido, el plan de estudios o currículo es considerado la materialización de una disciplina, dicta los criterios de pertinencia y de validez, además de reflejar los intereses de la universidad o institución de educación superior, para una determinada carrera de grado (Balza-Franco, 2016). Latinoamérica tiene ciertas particularidades, que dan un contexto diferente a esta investigación, pues las revisiones curriculares, la actualización de los planes de estudio y la inclusión de temas innovadores son poco habituales, debido la falta de docentes o expertos dedicados a estos temas, especialmente en los programas de ingeniería (Barriga, 1993). En este sentido, se considera que, en general, el plan de estudios de los programas de ingeniería es la guía o mapa que refleja la formación que tendrá el egresado (Balza-Franco, 2016). Para realizar la evaluación del plan de estudios se tomó una muestra aleatoria de universidades que ofrecen carreras de grado o licenciaturas en ingeniería de Colombia, Argentina, Perú, México y España.

2.3.2. Encuestas

Tomando como base la muestra de universidades mencionadas, para la evaluación curricular se dispuso de una muestra de estudiantes, docentes y egresados de las carreras de ingeniería, a los que se les planteó una encuesta sobre el conocimiento y aplicabilidad de la EA y la

EDS. Las encuestas fueron realizadas online con la finalidad de tener una mayor cobertura y aumentar la muestra. Para el diseño de la encuesta se realizó una evaluación de referentes bibliográficos de diferentes bases de datos, especialmente Web of Science, así como las publicaciones de las Naciones Unidades referentes a la EA y la EDS. Se utilizó el programa R para realizar la validación y análisis estadístico de los resultados obtenidos de las encuestas.

2.3.3. Validación

Con el fin de garantizar la calidad y la precisión de la medida de la encuesta, se efectuó una validación formal de las herramientas utilizadas. Para esto se utilizaron los métodos de validez que se refieren a la exactitud en cuanto a cuantificación, también se midió la confiabilidad que expresa si el instrumento aplicado cumple con el objetivo de medición y es consistente en el tiempo (Oviedo & Campo-Arias, 2005). Como es bien sabido, el test de Alfa de Cronbach es un índice utilizado para determinar la magnitud en que los ítems de una medida están correlacionados. Este índice evalúa, entre otras cosas, el error factorial específico y el error por respuesta al azar, fundamentales para analizar la validez y confiabilidad de los resultados (Schmidt & Hunter, 2004; Warrens, 2015).

3. ESTADO DEL ARTE

El ser humano, y la sociedad en general, se encuentran en riesgo de supervivencia debido al modelo de desarrollo económico y social, que se estandarizó a nivel global durante el siglo XX y que ha tenido su apogeo en la actualidad. Dicho modelo se ha caracterizado por una predominancia del bienestar individual por encima del bien común, teniendo como consecuencia, entre otras cosas, el cambio climático y la degradación de los recursos naturales (Sosa et al., 2010).

Para poner freno a estos problemas medioambientales, se han propuesto diferentes iniciativas en todas las disciplinas y áreas de las ciencias. Por su parte, desde la educación, se ha tratado de abordar estas dificultades con estrategias que buscan estructurar un pensamiento crítico y formar a las personas para que reconozcan el problema ambiental y que a su vez busquen una solución, en este sentido se destacan dos corrientes de educación: la EA y la EDS (Barry, 2006).

Tanto la EA como la EDS buscan, utilizando conceptos y caminos diferentes, frenar los problemas ambientales existentes y garantizar el bienestar ecológico para las generaciones futuras. La EA tiene un recorrido histórico mayor que la EDS, y sus características populistas calan más, por su filosofía, en países económica y socialmente emergentes (de Andrade Guerra et al., 2018; González-Gaudiano, 2016). Por otro lado, algunos países han adoptado la EDS en sus sistemas educativos, especialmente los países del norte de Europa. Es difícil encontrar un consenso sobre cuál de los dos modelos resulta más adecuado para abordar los

problemas ambientales, especialmente en los círculos académicos e investigadores, debido, en gran medida, a las características ideológicas que poseen cada una de las corrientes. Aún así, desde la ONU, se planteó la EDS como el reemplazo de la EA, pues es más actual en términos tecnológicos, pero, sobre todo, se considera que se encuentra más alineada con las metas e intereses económicos y sociales que deben cumplir los países en vías de desarrollo.

3.1. La EA y sus características

La EA ha sido el modelo o corriente de educación más importante a nivel global, en términos ecológicos y ambientales, consecuencia de una constante evolución y adaptación, que reconoce los cambios sociales y culturales de la humanidad y, sobre todo, tecnológicos, de los últimos años. Sin una fecha consensuada de su aparición escrita o promulgada, la EA aparece en la década de los años 1960 en diferentes artículos y conferencias. Este modelo consideraba diferentes propuestas sobre cómo proteger el medio ambiente, formando una amalgama de conceptos, herramientas y teorías que buscaban, ante todo, la preservación de los ecosistemas naturales (Stevenson et al., 2013).

La EA se centra en la conservación de los recursos naturales, es decir, es una contraposición a las corrientes desarrollistas y capitalistas, y fue la respuesta a los diferentes problemas que abordaba el planeta en las décadas de los 1960 y 1970, cuando se vivía la guerra fría, la guerra en Vietnam y circulaban, como nunca antes, imágenes de la pobreza y hambruna de algunos países. Esto impactaba, principalmente, en la población de Estados Unidos y algunos países ricos de Europa gracias al acceso masivo a información gráfica, principalmente la televisión,

sumado a publicaciones como “La primavera silenciosa” de Rachel Carson y la primera fotografía a color del planeta. Así la EA ganó fuerza a nivel mundial (Barry, 2006; Bennett, 2014; Stevenson et al., 2013; Vail, 2010).

La conservación de los recursos naturales es el centro de la EA, es decir, el tratar de mantener prístina la naturaleza y que los seres humanos se abastezcan de lo que generen (Ardoin et al., 2020; Asch & Shore, 1975). Este es el aspecto en el que más destaca la EA, pero es a su vez el que más conflicto ha generado, especialmente en un mundo globalizado, en constante crecimiento poblacional y económico.

Por otro lado, en la parte curricular, la EA implicaba decantar los diferentes puntos de vista ambientales en algo tangible, es así que en la primera conferencia intergubernamental mundial de EA organizada por las Nacionales Unidas en Tbilisi (Georgia, URSS), en 1987, se dieron a conocer los objetivos y características que debía tener la EA para formalizarse en los currículos de todos los niveles educativos en el mundo. En esta conferencia se establecieron los objetivos que debe cumplir la EA, a saber: conciencia, conocimiento, actitudes, habilidades y participación (Gille, 1996). Por su parte, en este mismo espacio de discusión se plasmó la primera definición formal de la EA:

> “*La educación ambiental es un proceso permanente en el cual los individuos y las comunidades adquieren conciencia de su ambiente, aprenden los conocimientos, los valores, las destrezas, la experiencia y, también, la determinación que les capacite para actuar, individual y colectivamente, en la resolución de los problemas*

ambientales presentes y futuros" (Martínez, 2010, p. 100).

Esta definición enmarca la esencia de la EA, que impulsa la modificación de la relación naturaleza-ser humano para, posteriormente, generar transformaciones sociales que lleven a que esa relación sea justa y recíproca (Carrasco & Vásquez, 2016). La EA, por lo tanto, busca el reconocimiento de la naturaleza como el actor más importante dentro de todos los factores que involucran el desarrollo, la vida y la cotidianidad del ser humano (UNESCO, 2012). Dicha búsqueda ha creado escuelas de líderes ambientales que buscan, a través de su representación, dar a reconocer los problemas ambientales de sus comunidades y entornos y que, así mismo, sean difusores de las estrategias exitosas de conservación que aplican en sus ambientes (Acosta-Castellanos & Queiruga-Dios, 2022).

Tanto es así, que la EA se convirtió en una fuente de generación de estrategias de mitigación y conservación de la naturaleza, donde intervienen aspectos biofísicos, sociales y políticos (Pita-Morales, 2016). Las ideas conservacionistas han calado más en los ideales de la sociedad y las economías emergentes, pues plasman la indiscutible realidad del capitalismo, visto desde la explotación comercial de materias primas en estos países, donde lo único que queda de la explotación de minerales, petróleo y otros recursos, por grandes compañías, es un medioambiente con daños irreparables y con pocos beneficios para las sociedades que lo habitan. Por esto, para las comunidades que viven bajo lo que provee la naturaleza, el mensaje de la EA es fácil de asimilar, pues el medio ambiente ha sido su fuente de supervivencia y no tiene sentido, para estas comunidades, deteriorarlo para explotar recursos que no van a

disfrutar.

3.2. La EDS y sus características

La EDS está fundamentada en el concepto y modelo del DS presentado en la asamblea general de las Naciones Unidas el 4 de agosto de 1987, en el informe titulado "Nuestro futuro común", conocido también como el informe Brundtland (Last, 1987). En el informe Brundtland se definió el DS de la siguiente forma:

> *"El desarrollo sostenible es el desarrollo que satisface las necesidades del presente sin comprometer la capacidad de las generaciones futuras para satisfacer sus propias necesidades*" (Last, 1987, p. 291).

A partir de ese momento, todas las naciones que no habían alcanzado un desarrollo económico y social debieron alinearse con este estándar, que buscaba un equilibro que involucrara, ineludiblemente, al medio ambiente con el ser humano (Waas et al., 2014).

Desde que se propuso el DS han pasado más de tres décadas y se observan algunos avances, pero es difícil encontrar un camino consensuado que marque la ruta para alcanzar este desarrollo. Actualmente no existe ningún país que se considere desarrollado en términos sociales y económicos, y que lo haya logrado utilizando este modelo. El DS busca equilibrar, cuidar el medio ambiente, la sociedad y la economía, con la finalidad de conseguir el bienestar humano, esto hace que la característica principal del DS y, por lo tanto, de la EDS,

sea que ambas se reconocen como corrientes antropocentristas (Bush et al., 2017; Kopnina, 2014).

Para lograr el DS se han aplicado muchas herramientas, todas ellas propuestas y consensuadas desde la ONU, la última fue la formulación de una serie de objetivos y metas para alcanzar el DS, denominados objetivos de desarrollo sostenible (ODS) (Biasi et al., 2019). Algunos autores hacen énfasis en la educación como medio para lograr dichos ODS (Becker, 2018; McKeown & Hopkins, 2003), para lo cual establecieron que el DS debía formar parte de los planes de estudio y figurar en los modelos educativos, con la EDS como modelo de estructuración (Higgitt, 2006).

La EDS se define como:

> "*el proceso de equipar a los estudiantes con el conocimiento y la comprensión, las habilidades y los atributos necesarios para trabajar y vivir de una manera que salvaguarde el bienestar ambiental, social y económico, tanto en el presente como para las generaciones futuras"* (Ramos Torres, 2021, p 7).

En este sentido, la EDS es una herramienta para llevar la teoría del DS a la práctica, lo que conlleva muchos interrogantes especialmente en las instituciones de educación superior. Resulta, por tanto, que no es fácil encontrar consensos y claridad sobre la forma de implementarlo en este nivel educativo, y surgen cada vez más interrogantes sobre cómo abordar su incorporación. Algunos de estos cuestionamientos se centran en cómo incorporar

el DS en cada disciplina mediante la EDS (Sánchez-Carracedo & López, 2020), lo que implica que los profesionales deberán estar en capacidad de aportar, desde su quehacer diario, la aplicación equitativa de los pilares del DS: sociedad, economía y medio ambiente.

Así pues, las universidades deben empezar a entender y responder a las necesidades de un nuevo mercado laboral más holístico, desde el punto de vista del desarrollo; es decir, la corresponsabilidad entre el empleador y la universidad lleva a una responsabilidad entre la demanda de profesionales alfabetizados en DS y la oferta de estos mismos desde las universidades (Ramos et al., 2015). Por lo tanto, las universidades están llamadas a promover la EDS para impulsar una transición hacia la sostenibilidad mediante la enseñanza, la investigación y la participación activa de toda la comunidad académica (Lozano, 2012; Lozano et al., 2015; Mbah, 2019; Radinger-Peer & Pflitsch, 2017).

3.3. La ingeniería ambiental en Colombia y su relación con la EA y la EDS

La ingeniería ambiental surgió de la evolución de la ingeniería sanitaria y de la especificación en temas ambientales en la ingeniería civil (García Durán, 2007; Maroto, 1969). La aparición de esta ingeniería en Colombia y Latinoamérica data de finales de la década de los años 1980 y principios de los 1990. Los currículos de ingeniería ambiental son comunes en las ingenierías, con áreas de formación centrados en las ciencias básicas, asignaturas de ingeniería aplicada y ética o humanismo. La ingeniería ambiental en Colombia es una titulación de grado que, usualmente, se cursa en cuatro o cinco años, dependiendo de la universidad que la imparta. Existen a su vez carreras de postgrado a nivel de especialización

y másteres con la misma denominación. La ingeniería ambiental, a diferencia de otras ingenierías en Colombia, no está regulada por ninguna norma o ley para su ejercicio, pero se encuentra dentro del Consejo Profesional Nacional de Ingenierías (COPNIA), que otorga el permiso de ejercer profesionalmente la carrera. Por su parte, las variaciones curriculares son sugeridas por parte de la Asociación Colombiana de Ingenierías (ACOFI), y no son de obligado cumplimiento, pero son tenidas en cuenta dentro de la revisión para la aprobación y renovación de programas de ingeniería por el ministerio de educación nacional del gobierno de Colombia. En este sentido, no existe un documento que sugiera, desde ACOFI o COPNIA, que se involucre la EA o la EDS dentro de los currículos de ingeniería ambiental o alguna otra ingeniería (Acosta Castellanos et al., 2020; Acosta Castellanos et al., 2020b; García Durán, 2007; Hernández-Diaz et al., 2020; Portocarrero-Sierra et al., 2020; Rendón López et al., 2018).

Por lo tanto, la relación entre la EA y la EDS con la ingeniería ambiental es poco visible en los currículos, pero existe una necesidad evidente de incluir alguna de estas dos corrientes dentro del plan de estudios de esta ingeniería, especialmente evidenciada a partir de investigaciones curriculares.

La EA es más perceptible curricularmente en la ingeniería ambiental en Colombia, aunque de manera muy poco profunda, por su parte la EDS es casi nula en los currículos (Acosta Castellanos & Queiruga-Dios, 2022b). Este hecho se debe a que la EA es impulsada por las políticas educativas, aunque, en mayor medida en la educación básica, es decir, primaria y

secundaria, y no en la educación superior (González-Gaudiano, 2016); esto se refuerza por la consideración de que por ley existe la denomina autonomía universitaria, donde este tipo de corrientes, con tintes ideológicos, puede tener resistencia y no ser aceptada por los académicos.

Con la investigación realizada en esta tesis se logró identificar los vacíos existentes en formación docente y estudiantil en las titulaciones de ingeniería, especialmente en la ingeniería ambiental. Así mismo, se logró proporcionar una herramienta útil, como la inclusión de una asignatura que llenara el vacío de formación de los estudiantes, lo que ha sido posible gracias a una evaluación curricular que incluye revisiones sistemáticas de la literatura, encuestas y modificaciones curriculares.

4. ARTÍCULO 1

Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America

Resumen

La EA se ha convertido en la única herramienta para la sostenibilidad ambiental en los procesos de formación en Colombia, tanto para los ciclos básicos de primaria y secundaria, como para la educación universitaria. La EA tiende a transformar las acciones humanas en la naturaleza, a partir de conocimientos multidisciplinares que apoyan la toma de decisiones, su objetivo es generar un cambio en el comportamiento social para lograr la recuperación, conservación y preservación del medio ambiente. En Colombia, la EDS está integrada en la EA. Estos dos modelos educativos buscan ayudar a lograr los ODS, con la finalidad de alcanzar el bienestar económico y social de las naciones para las generaciones actuales y las futuras. La ingeniería ambiental es una carrera de grado relativamente nueva en Colombia y Latinoamérica, que se inició en los años noventa, por lo tanto, es poco usual que la EA esté incluida en los currículos.

4.1. Objetivos

Los objetivos de esta investigación han sido los siguientes:

- Identificar, a través de una revisión curricular de los planes de estudio de ingeniería ambiental y también mediante la realización de encuestas a estudiantes de ingeniería ambiental, el nivel de inclusión de la EA en Latinoamérica.
- Identificar las fortalezas en los currículos y la presencia de la EA en las diferentes asignaturas de la titulación.
- Definir las oportunidades de mejora curricular en función de las necesidades de los estudiantes.

4.2. Metodología

La metodología utilizada en este estudio se basó en la revisión de los currículos de los programas de ingeniería ambiental de Colombia. Es importante destacar que Colombia, y en general, Latinoamérica, tiene ciertas peculiaridades, como la duración de los estudios de ingeniería, que son de 5 años, distribuidos en 10 semestres académicos. La metodología utilizada se dividió en dos etapas diferentes: la revisión curricular basada en la información pública de las universidades, que se refleja en el plan de estudios y sus asignaturas y, por otro lado, la aplicación de una encuesta que demuestra el conocimiento de los estudiantes sobre aspectos curriculares.

Para la evaluación del plan de estudios se utilizó información pública de una muestra de seis titulaciones de ingeniería ambiental en Colombia, seleccionando universidades con acreditación de alta calidad por el Ministerio de Educación Nacional. Se revisaron cursos o asignaturas, así como la existencia de la EA en los objetivos propuestos por cada universidad

para la ingeniería ambiental. Una vez revisada la información, se comprobó con los estudiantes de estos programas, a través de encuestas, la inclusión de la EA en su formación. La información proporcionada por los estudiantes se comparó con el plan de estudios para, finalmente, llevar a cabo una discusión sobre la formación de estos ingenieros en EA.

4.3. Resultados

Se analizaron todas las asignaturas de los planes de estudio de las universidades que participaron en este estudio y el análisis indicó cuáles abordaban directa o indirectamente los principios de la EA. En este sentido, se encontraron algunas asignaturas donde el uso de herramientas de EA o EDS resulta fundamental. Según los análisis realizados, los planes de estudio en Colombia tienen una relación muy estrecha con el saneamiento básico, lo que indica un retraso en el proceso de actualización del plan de estudios de ingeniería ambiental. La mayoría de los estudiantes encuestados consideró que la EA forma parte de su formación académica. Además, el 38 % de los estudiantes de la Universidad El Bosque y el 61,2 % de la Universidad Santo Tomás coincidieron en haber recibido formación en EA.

4.4. Conclusiones

Los planes de estudio de ingeniería ambiental en Colombia no son apropiados para las necesidades futuras del medio ambiente ni para las demandas actuales de los estudiantes, especialmente en EA. Si bien los estudiantes y las metas del país indican la necesidad de un ingeniero ambiental que conozca y maneje estrategias al respecto, los planes de estudio en

Colombia incorporan solo el 5 % (en promedio) de estos aspectos. Por lo tanto, el camino a seguir es que la ingeniería ambiental se actualice para que su plan de estudios responda, no solo a las necesidades de los estudiantes, sino también a los desafíos ambientales globales y se alinee con iniciativas como los ODS propuestos por la ONU. En ese sentido, fue posible identificar que los estudiantes ven la necesidad de un curso enfocado a la EA en las seis universidades analizadas.

Con la encuesta realizada se identificaron aportes valiosos de los planes de estudio y se constató el hecho de que muchas asignaturas incluyen formación en actitudes proambientales en el marco de la EA, especialmente en asignaturas de niveles superiores, que, en Colombia, corresponden a asignaturas del área de ingeniería aplicada. Sin embargo, se observó que en las asignaturas del área de ciencias básicas (biología, matemáticas, cálculo, física y química), que se imparten en los primeros cursos, es necesario implementar contenidos relacionados con la EA.

sustainability

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Article

Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America

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Abstract: Environmental education (EE) has become the only tool for environmental sustainability in training processes in Colombia, for basic cycles in primary and secondary, as well as university education. EE tends to transform human actions in nature, based on multidisciplinary knowledge that supports decision-making. Its goal is to generate a change in social behavior in order to achieve the recovery, conservation, and preservation of the environment. In Colombia, education for sustainable development (ESD) is embedded in EE. These educational models (EE and ESD) seek to achieve sustainable development goals (SDGs), which generally seek the economic and social well-being of nations, both for current and future generations. Environmental engineering is a relatively new degree course in Colombia and Latin America since it appeared in the mid-nineties, and it must involve EE within its curriculum. Students are trained in this trend. This research intends to demonstrate, through a curricular review of the environmental engineering curricula and also surveying students from this degree, the level of inclusion of EE in Latin America. Strengths are identified in the curricula, such as the strong presence of EE in disciplinary subjects and opportunities for improvement based on the needs of the students. The situation in South America is also included in this study.

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

1. Introduction

Currently, humanity faces changes that appear to be irreversible. These changes are the result of bad actions and social development, with little or no environmental responsibility, establishing a series of global challenges such as climate change and the degradation of natural resources [1].

These challenges also concern universities and their programs, so much so that broader definitions are found about the integration of the environment into these programs, Vidiella, defined the university as "a place where awareness must be created so that humans, through their activity, have promoted socioenvironmental changes in recent years; likewise, integrally train people so that they are capable of understanding society and intervening in it with the aim of improving it" [2]. Environmental education, as well as education for sustainable development, has become two currents within comprehensive

training in higher education, with the goal of protecting natural resources for future generations using different concepts and paths.

EE has historically more weight than ESD. For this reason, countries like Colombia have decided to focus their educational policy towards EE, neglecting ESD [3,4]. However, it is assumed that due to the characteristics of university environments, where research and scientific advances are born or amplified, the novel characteristics of EDS should at least be addressed or evaluated [5].

Education for sustainable development is defined as "the process of equipping students with the knowledge, understanding, skills and necessary attributes to work and live in a way that safeguards environmental, social, and economic well-being, both in the present and for future generations" [6]. Moreover, ESD's aim is to develop a comprehensive transformation of educational systems to promote skills, knowledge, and values, and to equip people with the skills to make them able to cocreate a sustainable future [7]. ESD is based on the concept and model of sustainable development presented at the United Nations (UN) general assembly on 4 August 1987. The report entitled "Our common future", also known as the Brundtland report [8], was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Thereafter, all nations that had not achieved economic and social development have pointed to this model, which seeks a balance that inevitably involves the environment, since intergenerational equity is not possible without involving this factor [9]. More than 30 years have passed since this model was proposed, and some progress has been noticed, but it is difficult to reach an agreement about the route to achieving this type of development. To overcome these impasses, different strategies from the UN have been discussed; the last one is the formulation of a series of guidelines to achieve, called "sustainable development goals" [10].

In order to achieve the SDGs, it is necessary to do it through education [11,12]. This is why sustainability should be involved in the curricula and educational models, emerging as the concept of education for sustainable development [13].

Although there is no simple or consensual definition for EE, it can be classified as heterogeneous and diverse since it concerns basic primary education to higher education, regardless of the area of knowledge. EE provides a common, clear, and defined core, as it raises the need to promote a change in behavior in relation to the environment, apart from the approach or the didactic strategy that is used [7]. During a conference on environmental education, to give an answer to the complexity of the environment and its links with biological, physical, social, cultural, and socioeconomic factors was stated [14]. In the same way, it is usual to see EE emphasizing awareness and providing tools to acquire information on environmental sustainability, focusing on promoting ecological behaviors and critical thoughts about excessive consumption [15,16]. Information for smart decision-making in the face of the environment and how to protect it was also included in that conference [17,18].

In universities, EE must guide students to know their environment, both in human actions and acts of nature, and how to generate an action strategy to protect the environment. To make this possible, it is necessary to teach students in a practical, theoretical, and innovative way, with actions and tools aimed at improving the environment [19]. In this sense, many of the universities face a great challenge since so few of them involve the environment within their functions. In Latin America, environmental education is still seen as something that only involves primary and secondary education [4], but not higher education, since it implies voluntary changes in restructuring the curricula of undergraduate and postgraduate programs. Therefore, this change would imply recognizing the importance of the environment in people's lives and in the development of societies in the educational system. Therefore, it would imply the use of EE in the curricula and in the universities themselves [20].

Based on what has been described, the importance of EE and ESD can be inferred, not only in the evolutionary process of universities and their programs but also in the development that nations need to achieve. In Colombia and Latin America, bachelor degrees are the first stage in higher education; they should promote these models since this stage in formal education gives shape to the future of people and, therefore, of societies [21].

Environmental engineering arose from the evolution of sanitary engineering and civil engineering; both engineering degrees addressed environmental issues in their curriculum. More specifically, sanitary engineering is the area related to environmental health, whose objective, broadly speaking, is to analyze the effects of using toxic elements in the environment on human health [22], and civil engineering is in charge of water resource issues [23]. The creation of environmental engineering in Latin America is very recent, and the first environmental degrees emerged in engineering programs in Colombia and much of Latin America during the nineties. The first degrees were sanitary and environmental engineering, but, over time, the word sanitary was removed from the name, since environmental issues had gained more relevance within the curricula and were somewhat overcome, at least in the countries with the greatest advances, problems associated with a lack of basic sanitation. However, the curricula or study plans continued to have their foothold mainly only in the technique that was very inclined to that health origin.

The training of environmental engineers has a very clear curricular core and areas of training, such as basic sciences, basic engineering, formative research, applied engineering, and ethics or humanism, which will depend on the approach of the university that offers the program. This is because the environmental engineer seeks the technique to solve environmental problems, that is to say, to decontaminate and not to stop the contaminating action; making an analogy with medicine, i.e., the objective is curative, but not preventive.

Environmental education has become a part of everyday life around the world, addressing environmental problems by changing the curricula in higher education. Likewise, to include courses, subjects, or programs, seems to be the most adequate proposal for EE [24,25]. However, it has been shown that the curricular change has not been carried out by many universities, and those that have carried it out have not had satisfactory results [26]. On the other hand, it has also been shown that teacher–student integration, in a collaborative way, is most effective in addressing environmental education in higher education programs [27]. It is generally considered that university students who study programs related to the environment have a better perspective on environmental problems, and it would be assumed that they have better training in environmental education; this is not always the case [28].

The objective of this research is to identify the presence of environmental education in the training of environmental engineers in Colombia; this will contribute to the knowledge of whether training is deficient or appropriate. To achieve this objective, a search was carried out on the environmental engineering programs that stand out for the quality accreditation granted by the Colombian Ministry of Education. From these, a sample of 6 programs was taken for the revision of the curricula or study plans to identify the existence of EE. On the other hand, the information was corroborated through surveys in a sample of two university programs through the consultation of their students. This survey allowed us to identify training aspects in EE, inside and outside the curriculum. The results will serve as input for the improvement of these environmental engineering programs, not only in Colombia but in several places where this type of engineering is offered.

2. Environmental Education in Environmental Engineering in Colombia

In a society defined as a "society of knowledge", education evolves with greater speed. In the decade between the 1990s and 2000s, virtual education was not conceived, but 10 years later, it began to grow, generating changes and new paradigms. Entirely virtual universities arose in this context, leading education to evolve along with social and technological evolution [29]. The same happens in environmental terms, i.e., needs are increasing and the requirements at the government level are aligned according to the terms of reference established by the UN. In this sense, the greatest current challenge is the SDGs; however, countries like Colombia do not recognise these needs and, therefore, ESD is not well known, even when universities or higher education institutions (HEIs) are considered major contributors in promoting environmental sustainability [30]. Latin America, in general, seems to have the same drawback, and most references to ESD are given in primary schools and by nongovernmental institutions or foundations [30]. However, there are a few approaches to ESD by universities [13].

Universities in Colombia, as in other places, add value to the regions where they are located because, in addition to generating a diaspora of cognitive growth, they contribute to the creation and improvement of links between companies and economic, environmental, social, and cultural managers. Therefore, it could be said that education, in general terms, seeks to give people the tools of validated knowledge to solve contemporary problems and to be dynamic, adaptive, and capable of leading us to generate new knowledge by promoting changes and improvements in society. In this sense, EE and ESD arise as a result of the historical context and the uncertainty of a future in social terms due to the existence of human species, which we have faced since the end of the 20th century. Universities are being forced to face these challenges by application of these two currents: EE and ESD.

Universities play a relevant role in solving the current socioenvironmental crisis; the environment requires preparing its members to face the challenges that come with it: climate change, the degradation of natural resources, territorial conflicts arising from the expansion of the agricultural frontier, the generation of solid waste, and the contamination of water sources, among many other issues [31]. Teaching and research must be the main agents of change based on responses to the problems and challenges of society, dealing with issues related to the environment in any type of educational context, such as responsible consumption, conservation of biodiversity, or the economy, among others. This leads to the promotion and strengthening of environmental education processes [31,32].

In line with these needs, some universities that are committed to the environmental issue have sought to create participation programs, implement environmental management systems such as EMAS or ISO 14001, as well as create environmental academic lines and undergraduate and postgraduate programs, among many other things [33]. Some bachelor and engineering degrees that are dedicated to the environment are gaining more and more spaces in universities; one of the most common ones in Latin America is environmental engineering, which is rich in curricular uncertainties that must be investigated in order to strengthen graduate students so that they can face the changing environment on a planet increasingly in need of solutions to its environmental problems [34].

In contrast, it has been noticed that higher education is not playing this important role, especially in Latin America, since the effect on students and graduates, in proenvironmental attitudes and solutions to environmental problems, is minimal [35]. The universities, therefore, must increase their efforts so that the environmental permeates all its spheres of action: teaching, research, operations, and social responsibility [19,36], acting in accordance with global guidelines on environmental education such as the Talloires Declaration of Bergen, Turin, the University Charter for sustainable development, and many others [36,37], as well as determining whether ESD is the correct way to achieve the SDGs [38].

Environmental engineering exists in almost all countries, but it is seen in different ways; in most developed countries, it is part of the formation of civil engineering programs, focusing mainly on basic sanitation [39,40]. However, it has been expanded to cover topics such as air, soil, water, and independent civil engineering programs called environmental engineering. However, the needs and skills of the environmental engineer increasingly require changes that involve interdisciplinary and global contexts [41]. This adaptation is evident in countries like Canada, the United States, and Japan, but in regions such as Latin America, it seems to be stagnant in sanitation issues; therefore, it lacks an identity as a profession or discipline [42,43].

Environmental engineering is growing and spreading rapidly among universities in developing countries [38], but since this profession is not too involved in global changes and context needs, it is not responding to the real need of the environment.

Environmental education is a very widespread term in daily life in Colombia, but little is done about it in several universities in Latin America, where there has been little research and what has already been done is conceptual and theoretical [44]. Most of the research is dedicated to evidencing the need to implement EE, demonstrating through questionnaires that there is environmental damage, and focusing on the attitude and disposition of the students [4].

One of the weaknesses of EE is that it has devoted itself to theory and explanation through short masterclasses, with little time and sporadically, which does not create a bridge between theory and practice; this delimits the behavior that finally has a positive effect on the environment [44,45].

At this point, it is important to conclude that, in Colombia, ESD is not formally seen or used by this name, but it is embedded in EE. In other words, within the actions that Colombia classifies as EE, many are actions and forms of ESD [46,47]. That is why in the development of this study, it is important to keep in mind that when EE is mentioned, it is not an ancient concept anchored solely to the generation of consciousness and a certain romantic sense. On the contrary, it is a concept that has evolved [48–51], where technical concepts are the support for decision-making in order to generate a change in consumer attitudes and responsibility towards the environment. It is usual to see EE generating spaces for educational transformation, with support from biology, physics, and economics [1,48,50,52], far from classic EE. This is not intended to erase some characteristics or criticisms of EE, such as the political inclination or the mandatory need to have physical contact with ecosystems in order to protect them, marked in "if I know it, I protect it", among other criticisms [53,54]. In turn, its ESD counterpart also has criticisms, such as anthropocentrism [55,56].

3. Methodology

3.1. Review of the Environmental Engineering Curriculum

It was taken as a premise that the study plan is the materialization of the curriculum. It includes what is considered as valid knowledge and sets out the criteria of relevance and validity for the discipline, in addition to reflecting the interests of higher education institution [57]. It is important to highlight that Colombia has certain peculiarities, which give a different context to this research, since curricular reviews, updates of study plans, and the inclusion of innovative topics are unusual due to the lack of teachers or experts dedicated to these topics, especially in engineering programs [57,58]. In this sense, in general, it is taken as a basis that the curriculum in engineering programs in Colombia is a central tool, establishing itself as a guide in the structure and training of graduates [59]. Engineering degrees in Colombia usually last 5 years, distributed in 10 academic semesters.

For the methodological development of the study plan, public information was taken from a sample of 6 (n = 6) environmental engineering programs in Colombia, selecting universities that are recognized with high-quality accreditation by the Ministry of National Education. The academic courses or subjects were reviewed, as well as the existence of environmental education in the objectives proposed by each university for environmental engineering. Once the information was reviewed, it was corroborated with the students of these programs through surveys, verifying that EE is included in their training. The information provided by the students was compared with the curriculum to finally carry out a discussion about the training of these engineers in environmental education. Figure 1 shows the EE verification process in the training of environmental engineers in Colombia.

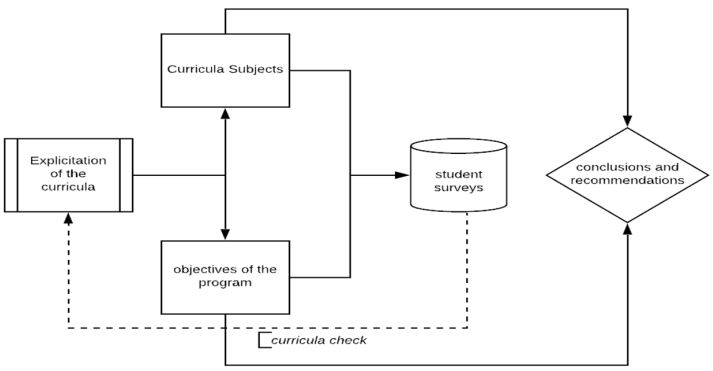

Figure 1. Verification methodology of environmental education (EE) in environmental engineering in Colombia.

3.2. Collection of Curricular Data

A search was carried out for terms such as environmental education and education for sustainable development within the study plans, that is, to identify whether the terms were explicit within the study plan or there were courses with this name. Likewise, the public information on the web pages of the engineering programs was searched, and it was verified that there are some references to EE and ESD in the syllabus or contents of the environmental engineering programs.

Environmental engineering is currently offered in 46 universities in Colombia, but only 14 are accredited. Higher education institutions that hold high-quality accreditation indicate the quality in academic processes. To opt for such a title is voluntary and governed by law, it ensures that both universities and programs meet national and international standards [59]. From the total amount of accredited universities (n = 11) for the year 2019, a random sample of 6 (n = 6) universities was taken. This sample corresponds to 42% of the total, namely, Santo Tomás University, Libre University, El Bosque University, Boyacá University, Pedagogical and Technological University of Colombia, and La Salle University.

3.3. Surveys

To corroborate the analysis in the curricula or study plans, a survey was conducted in two universities of the general sample. From the Universidad del Bosque, 95 students were interviewed (n = 95), with 155 students from the Universidad Santo Tomás (n = 155). All of them were active students of environmental engineering programs. The rest of the universities either refused to participate or there was no official response. The questionnaire included 16 questions that are shown in Table 1. A confidence interval, according to Equation (1), and a standard normal distribution were used [60].

$$p - e < \pi < p + e \quad (1)$$

Table 1. Questionnaire for environmental engineering students around EE.

Q1	I think that environmental education is part of the training of an environmental engineer	Q9	Within your academic engineering training, you have been trained or oriented in environmental education strategies
Q2	I think I am trained under the precepts of environmental education	Q10	Indicate the type of training
Q3	In which academic courses do you consider that you are trained in environmental education?	Q11	I think that within the field of action of the environmental engineer it is important to obtain tools to develop environmental education actions
Q4	I have taken subjects that incorporate environmental education themes into their content	Q12	I consider that the curriculum or study plan of environmental engineering provides significant tools to develop environmental education activities
Q5	I have carried out environmental education activities	Q13	You promote the development of good environmental practices in other people
Q6	Indicate in which courses you have carried out the activities	Q14	I would like to be part of the formulation and implementation of environmental education projects
Q7	Sometimes, outside academic training activities, you have been trained or oriented in environmental education strategies	Q15	From the following training areas of the environmental engineering program, indicate those in which you consider that you obtain tools for the development of environmental education activities: Basic Sciences, Basic Sciences of Environmental Engineering, Applied Environmental Engineering, Other
Q8	Indicate in which academic activities were you trained in EE	Q16	I think it is important that the curriculum of an environmental engineering program includes a subject focused on environmental education

This formula allows the estimation of the proportion of students who meet a certain condition according to the survey questions. The value π represents the population proportion (what we want to estimate) and it is estimated by $p = \frac{x}{n}$, which corresponds to the sample proportion, where x is the

number of successes in the sample and n the sample size. The value e represents the margin of error of the estimation, which is defined as $e = Z\sqrt{\frac{pq}{n}}$; the value of Z allows us to find the critical point for a confidence level 1-α.

The sample included 85.2% of students with ages between 18 and 22; 8.4% were between 23 and 29 and 6.4% were between 16 and 17 years old. On the other hand, 65.6% of the students were female and 34.4% male. In addition, 72% were studying from the third to the seventh semesters, 16% in the eighth and ninth semesters, and 12% were studying in the first and second semesters. It is important to take into account that higher education in Colombia is divided into semesters. In total, 100% of the surveyed students studied environmental engineering; from these, 38% studied at El Bosque University while 62% did so at the Santo Tomás University.

4. Results

4.1. Analysis of the Curricula

All courses from the curricula and from all semesters were analyzed; this analysis indicates which ones directly or indirectly address the principles of EE. In this sense, some courses were found where it is essential to use EE or ESD tools. For example, the waste management course, which is common in all environmental engineering programs. In this course, modules are connected through environmental education, i.e., with topics such as source reduction, sorting, reuse, recycling, and many other tools that seek to minimize the final disposal of solid waste. Other courses include EE or ESD tangentially through the teaching of ISO 14001 standards, which is also common in all the reviewed study plans. Some courses like environmental policy, ecology, and environmental impact are in this same line, but they only represent, on average, 5% of the courses in the study plans, with the environmental engineering program of the Pedagogical and Technological University of Colombia having the most representativeness, namely, 8% of subjects had courses dedicated to EE.

Only the Santo Tomás University offers an elective course dedicated exclusively to ESD. In contrast, particularities were found in the study plans that include courses exclusively dedicated to EE and its promotion. It is important to highlight that it is not very representative compared to the total; in this case, the Pedagogical and Technological University of Colombia also stands out with 4%.

Table 2 shows a summary of the quantitative analysis of academic spaces that directly or indirectly deal with EE structure. It is important to highlight that there is evidence of a disarticulation in the training process focused on promoting EE, but the homogeneity is remarkable among the programs of all the universities in the sample, which focus their subjects on attitudes typical of EE, especially the case of solid waste management.

Table 2. Analysis of the academic load designated to EE in the environmental engineering programs of the sample.

	University Offering Environmental Engineering	Academic Spaces with a Focus on EE or ESD	Academic Credits Focus on EE or ESD	% of Courses Focus on EE or ESD	Exclusive Courses for EE	Exclusive Courses for ESD
1	Universidad Santo Tomás	3	12	5%	0	1
2	Universidad El Bosque	5	15	6%	1	0
3	Universidad Pedagógica y Tecnológica de Colombia	4	12	8%	2	0
4	Universidad Libre	2	6	3%	0	0
5	Universidad de Boyacá	3	12	5%	1	0
6	Universidad de la Salle	3	12	5%	1	0

4.2. Surveys

Most of the surveyed students considered that environmental education is part of their academic training. In addition, 38% of the students of the El Bosque University and 61.2% from Santo Tomás University agreed that they had been trained in EE. In the questions related to the content of the subjects

that are associated with EE, 56.4% of the students of the Santo Tomás University answered that their course content incorporated topics of EE in contrast to 33.6% of the students of El Bosque University.

In the case of students in Semesters 6 to 10, it was observed that 20% of the students stated that environmental legislation incorporates EE topics, followed by environmental solutions (14.8%). In Environmental Management and Environmental Impact courses, 10.4% of students answered the same. In most of the subjects of the applied engineering area, EE topics were incorporated, but in different percentages.

Subjects in the area of basic engineering, which correspond to Semesters 4 to 6, incorporate EE topics: 30.8% of the students stated that the introduction to environmental engineering incorporates EE topics, followed by topics of ecology and microbiology with 18.8% of students each. In the subject of environmental economics, 11.6% of the students affirmed it. In the area of basic sciences, 6.4% of the students stated that in biology, EE topics were incorporated; in chemistry, 0.8% of the students stated that EE topics were incorporated.

In general, it is found that 94% of the students affirmed that in the applied engineering area, EE themes were used; 47.6% in basic engineering, 7.2% in basic sciences, 2% in electives, and 2% in all subjects. In addition, 70% of the students carried out environmental education activities. The activities in which the surveyed students, who carried out EE activities within the subjects, had participated are summarized in Table 3.

Table 3. EE activities that students do in environmental engineering subjects.

Activities	Percentage
Community work	56%
Personal activities	29%
Research projects	6%
Field trips	8%

Among the community work activities that the students develop are waste collection, tree planting, cleaner production, talks in schools, colleges, and industries, application of the 3Rs (reduce, reuse, and recycle), waste management, reforestation, river cleaning, biogas generator, creation of tourist trails, and green markets. Among the personal activities are training, courses, forums, seminars, energy- and water-saving, construction of environmental education booklets, waste separation, calculating the carbon footprint of homes, environmental awareness, measuring water quality, debates, readings, and the study of wetlands. Likewise, research projects in which the students participated were environmental management plans and cleaner production at home.

In total, 52% of the surveyed students received training in EE strategies. Of these, 100% participated in extracurricular activities (application of SGDs, talks, conferences, forums, good practices, and workshops) and personal activities: 92.8% in subjects and 8.4% in complementary activities of the degree (3Rs management, field trips, resource optimization, risk analysis, investigation, the validity of environmental processes, and research). It is important to highlight this percentage value as it is an indicator of the tastes and needs of the students.

In addition, 98% of the surveyed students stated that it is important to obtain tools for the development of actions in EE, and 85% affirmed that the curriculum provides significant tools for the development of EE activities. Of the surveyed students, 90% would encourage other people to develop good environmental practices, 94% of the respondents would like to be part of the formulation and implementation of EE projects, 69% of those surveyed considered that they obtained tools for the development of EE activities in applied engineering subjects, 29% in basic engineering science subjects, and only 2% in basic science subjects.

Figure 2 describes that 95.2% of the surveyed students affirmed that EE must be part of the study plan; 59.6% from Santo Tomás University and 35.6% from El Bosque University. As random and

independent samples were taken in each of the two universities studied, it can be affirmed with 95% confidence that between 89% and 94% of the students from El Bosque University have indicated the importance of a subject focusing on EE within the study plan, while in Santo Tomás University, this rate is between 93% and 99%.

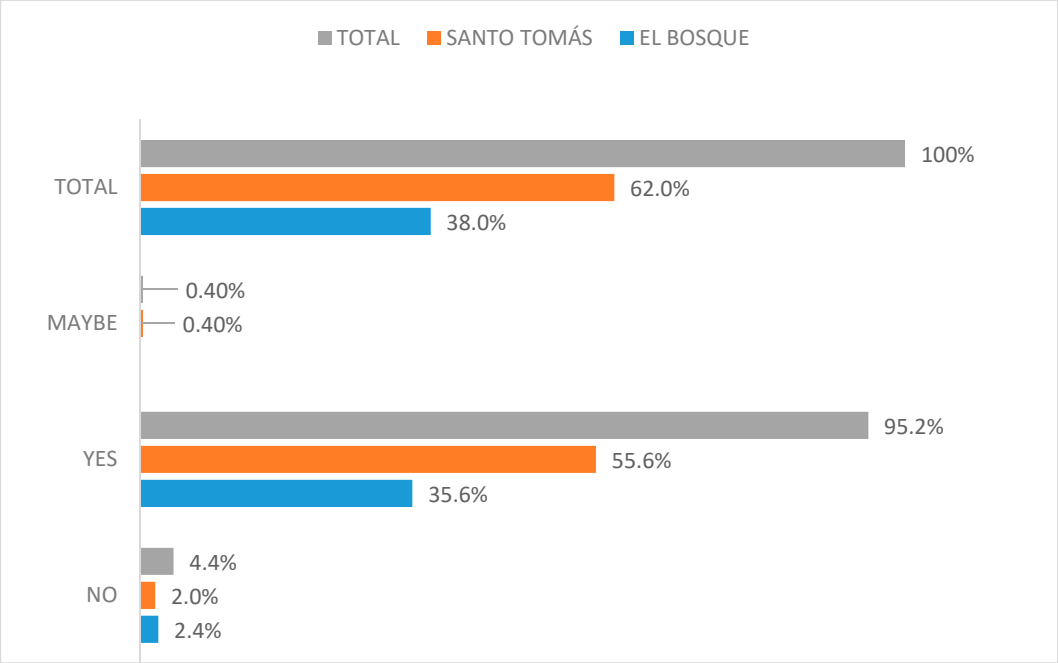

Figure 2. Environmental engineering students who stated the need to have the environmental education (EE) subject within the curriculum.

On the other hand, the students indicated that environmental engineering programs lack tools that help them prepare and train in EE; 66% of the surveyed students affirmed that the program they were studying lacked tools to train them in EE, 62% from Santo Tomás University and 38% from El Bosque University.

5. Discussion

In all the cases reviewed in the sample, the study plan remains dedicated, in greater proportion, to issues related to basic sanitation, which responds to the country's needs. This may indicate a delay in the process of updating the engineering curriculum. Therefore, the environmental engineering curricula in Colombia must change to adapt to the future characteristics of the country, where environmental engineering is not focused anymore on sanitation aspects, without neglecting it. More holistic aspects, such as environmental sustainability, must be addressed [53]. Colombia is among the Latin American countries with 97% potable water and sanitation coverage in urban areas, and it is expected to have 100% rural and urban coverage for both sectors by 2030 [61]. Therefore, environmental engineering must be directed towards an increasingly developed country, with more marked needs towards the protection of Colombia's natural characteristics, especially biodiversity and water supply, since it ranks 17th in biodiversity and 3rd in water reserves in the world. Moreover, it owns 50% of the moors that the planet has, in addition to 53% of the territory of natural forests, among many other environmental riches.

It is important to highlight that although it is assumed that university students of environmental or ecological degrees have strong training or conviction towards environmental education, this is not common; this is corroborated by the surveys carried out [28]. In addition, a lack of teacher training in universities is inferred, since most of the teachers have been trained under the same scheme as their students, that is, with few notions of environmental education [62], which in turn, demonstrates

the lack of support for higher education on environmental and sustainability issues. This makes it difficult for these places to become examples to be followed or used as a platform to achieve sustainable development goals [63].

Environmental engineering, like any other profession, must continually adapt to the challenges posed by the environment, especially this program that is born in modern times, where each decade represents unprecedented leaps in knowledge. This implies that it must evolve in line with the needs of the environment, but it seems that the processes of contamination and degradation of natural resources are overcoming [63]. In this situation, environmental engineers must not only respond from their technical base, which is their support and backbone, but from the ability to prevent pollution by promoting attitudes that generate awareness with the environment, seeking to conserve natural resources and its sustainability, generating synergies between the solution to a contamination process through techniques and mitigation in magnitude from environmental education. This seems to be clear to the students, but the curriculum has not responded adequately since most of the training in EE is done by self-management, that is, by the student's search and not because the university provides the tools within the curriculum to achieve it. There is also a notorious disparity between universities, both those surveyed and those analyzed; some have a greater inclination towards EE without this being representative, while others have even less representation of EE in the curricula.

Therefore, the need arises to incorporate EE to a greater extent in environmental engineering study plans, making them more consistent with environmental problems. This need is reflected in the results of the surveys applied to environmental engineering students; they want to become engineers who prevent and not only mitigate environmental impacts. This knowledge of prevention is achieved with appropriate and proven tools, such as the case of EE. In addition to the fact that it is in Colombia, incorporating ESD also serves as a way to achieve sustainable development. It was clearly evident that the curricula of this profession do not respond to the needs and demands of their own students; therefore, it could be said that they are not fully relevant. It is necessary to clarify that this research is not intended to affirm that this engineering curriculum is not responding in its entirety to the needs of the environment or that it is not entirely pertinent, but, rather, it must incorporate environmental education as a transversal tool to all its learning processes, assimilating the example given above of the solid waste subject, which is taught in the same way in all universities.

In all universities, it is common to see the core or subjects of the institution as those that give the distinctive feature to the student who graduates from the university, as well as subjects and content that urge the student to be trained in vital aspects such as ethics and other factors inherent to their discipline that promote interdisciplinarity [64]. The same can occur with environmental education or with sustainable development by incorporating environmental education or sustainable development in the syllabus [65]. This would not only respond to the needs of the students, but each subject would be aligned with policies such as the 2030 agenda and SDGs [66].

Another alternative is the inclusion, within the curriculum, of a subject such as environmental education or education for sustainable development. In this case, there is evidence of the success of this proposal in civil and environmental engineering in the University of Colorado, USA, where a sustainability subject that led students to have a broader environmental perspective was incorporated. This subject affected the students' concept of its importance in civil and environmental engineering [67].

6. Conclusions

Environmental engineering curricula in Colombia are not appropriate for the future needs of the environment nor for the current demands of the students, especially in environmental education. While students and the country goals indicate the need for an environmental engineer that knows and manages strategies in this regard, the curricula in Colombia incorporated only 5% (on average) of these aspects. Therefore, the way forward is for environmental engineering to be updated so that its curriculum responds not only to student needs but also to global environmental challenges and aligns with initiatives such as the sustainable development goals proposed by the UN. In this sense, it was

possible to identify that students see the need for a course focused on environmental education in both analyzed universities. Between 89% and 94% of students from El Bosque University and between 93% and 99% of students from Santo Tomás University determined that there is a need for this course.

To meet these needs, universities have to train, learn, and know about environmental education. Students have been using extracurricular strategies because they do not find another solution within the environmental engineering curriculum. Therefore, it was observed that 52% of students participating in the survey received training in EE strategies, and all of them participated in extracurricular activities, highlighting the self-management activities of 28.06% of those surveyed. Among the activities that were most frequently used by students are the 3Rs (reduce, reuse, and recycle) and readings, among others.

With the survey, it was possible to identify valuable contributions of the curricula and that many subject areas trained their students in proenvironmental attitudes within the framework of environmental education, especially the subjects that correspond to higher levels, that is, the area of applied engineering. However, it was observed that in the subjects of the area of basic sciences (biology, mathematics, calculus, physics, and chemistry), it is necessary to implement content related to environmental education.

It is important to continue research on environmental education in environmental engineering and to streamline the curricular update to make it relevant for Colombia to be a contributor to the sustainable development process in which it is framed. The constant evaluation and curricular self-evaluation of this engineering program will generate people with greater knowledge and holistic views that promote adequate management of natural resources. In these processes, universities must observe the progress that the country is making in aspects that are typically addressed by environmental engineers, such as water treatment and basic sanitation, and explore aspects such as sustainable infrastructure, air pollution, and technological development with the support of environmental education.

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References

1. Sosa, S.B.; Isaac–Márquez, R.; Eastmond, A.; Ayala, M.E.; Arteaga, M.A. Educación superior y cultura ambiental en el sureste de México. *Univ. Cienc.* **2010**, *26*, 33–49.
2. Vidiella, A.Z. *Enfoque Globalizador y Pensamiento Complejo: Una Respuesta Para la Comprensión e Intervención en la Realidad*; Graó: Barcelona, Spain, 1999; Volume 1, ISBN 84-7827-125-2.
3. De Andrade Guerra, J.B.S.O.; Gárcia, J.; Lima, M.D.A.; Barbosa, S.B.; Heerdt, M.L.; Berchin, I.I. A proposal of a Balanced Scorecard for an environmental education program at universities. *J. Clean. Prod.* **2018**, *172*, 1674–1690. [CrossRef]
4. Gaudiano, E.G.; Valdez, M.R.E. Enfoques y sujetos en los estudios sobre representaciones sociales de medio ambiente en tres países de Iberoamérica. *CPU-E Revista Investig. Educ.* **2012**. [CrossRef]
5. Tejedor, G.; Segalàs, J.; Rosas-Casals, M.; Rosas, M. Transdisciplinarity in higher education for sustainability: How discourses are approached in engineering education. *J. Clean. Prod.* **2018**, *175*, 29–37. [CrossRef]
6. Guide: University of the West of England. Education for Sustainable Development: Guidance for UK Higher Education Providers. *J. Educ. Sustain. Dev.* **2015**, *9*, 117. [CrossRef]
7. Holst, J.; Brock, A.; Singer-Brodowski, M.; de Haan, G. Monitoring Progress of Change: Implementation of Education for Sustainable Development (ESD) within Documents of the German Education System. *Sustainability* **2020**, *12*, 4306. [CrossRef]
8. Brundtland, G.H. *Informe de la Comisión Mundial sobre Medio Ambiente y el Desarrollo: Nuestro Futuro común*; ONU: New York, NY, USA, 1987; ISBN 9780969453802.

9. Waas, T.; Hugé, J.; Block, T.; Wright, T.; Benitez-Capistros, F.; Verbruggen, A. Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development. *Sustainability* **2014**, *6*, 5512–5534. [CrossRef]
10. Biasi, P.; Ferrini, S.; Borghesi, S.; Rocchi, B.; di Matteo, M. Enriching the Italian Genuine Saving with water and soil depletion: National trends and regional differences. *Ecol. Indic.* **2019**. [CrossRef]
11. Becker, G. *Climate Change Education for Sustainable Development in Urban Educational Landscapes and Learning Cities. Experiences Perspectives from Osnabrück BT- Lifelong Learning and Education in Healthy and Sustainable Cities*; Azeiteiro, U.M., Akerman, M., Leal Filho, W., Setti, A.F.F., Brandli, L.L., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 439–469, ISBN 978-3-319-69474-0.
12. McKeown, R. *Education for Sustainable Development Toolkit Version 2*; Univesity of Tennesse: Knoxville, TN, USA, 2002, ISBN 9789158641310.
13. UNESCO. *Shaping the Future We Want—UN Decade of Education for Sustainable Development (Final Report) Sustainable Development Knowledge Platform*; UNESCO: Paris, French, 2014; ISBN 978-92-3-100053-9.
14. UNESCO. *Intergovernmental Conference on Environmental Education Organized (Tbilisi, USSR, 14–26 October 1977). Final Report*; UNESCO: Paris, French, 1978.
15. Kibbe, A.; Bogner, F.X.; Kaiser, F.G. Exploitative vs. appreciative use of nature—Two interpretations of utilization and their relevance for environmental education. *Stud. Educ. Eval.* **2014**, *41*, 106–112. [CrossRef]
16. Frantz, C.M.; Mayer, F.S. The importance of connection to nature in assessing environmental education programs. *Stud. Educ. Eval.* **2014**, *41*, 85–89. [CrossRef]
17. Carleton-Hug, A.; Hug, J.W. Challenges and opportunities for evaluating environmental education programs. *Eval. Program Plan.* **2010**, *33*, 159–164. [CrossRef]
18. Ágnes, Z.; Szerényi, Z.M.; Széchy, A.; Kocsis, T. Greening due to environmental education? Environmental knowledge, attitudes, consumer behavior and everyday pro-environmental activities of Hungarian high school and university students. *J. Clean. Prod.* **2013**, *48*, 126–138. [CrossRef]
19. Lozano, R. Incorporation and institutionalization of SD into universities: Breaking through barriers to change. *J. Clean. Prod.* **2006**, *14*, 787–796. [CrossRef]
20. Ariza, C.P.; Rueda Toncel, L.Á. La educación ambiental: Una mirada desde el contexto universitario. *Boletín Redipe* **2016**, *5*, 116–124.
21. Ezquerra, A.A. La Universidad en la encrucijada. *Magriberia* **2011**, *5*, 25–44.
22. Maroto, J.P. La medicina y la ingeniería en la salud ambiental, Madrid: Instituto de España Real Academia Nacional de Medicina. *Rev. Obras Públicas* **1969**, *3046*, 87–113.
23. Durán, G.G. Surgimiento y evolución de la Ingeniería Ambiental en Colombia. *Rev. Ing.* **2007**, 122–130. [CrossRef]
24. Clark, S.G.; Rutherford, M.B.; Auer, M.R.; Cherney, D.N.; Wallace, R.L.; Mattson, D.J.; Clark, D.A.; Foote, L.; Krogman, N.; Wilshusen, P.; et al. College and University Environmental Programs as a Policy Problem (Part 1): Integrating Knowledge, Education, and Action for a Better World? *Environ. Manag.* **2011**, *47*, 701–715. [CrossRef]
25. Șterbuleac, D.; Toma, O. Environmental education through a University Eco-Consortium. *Appl. Environ. Educ. Commun.* **2018**, *19*, 62–73. [CrossRef]
26. De la Harpe, B.; Thomas, I. Curriculum Change in Universities. *J. Educ. Sustain. Dev.* **2009**, *3*, 75–85. [CrossRef]
27. Șterbuleac, D.; Toma, O. The overlooked role of academic environmental organizations in addressing environmental education issues. *Appl. Environ. Educ. Commun.* **2018**, *18*, 91–94. [CrossRef]
28. Liu, S.-C.; Lin, H.-S. Exploring Undergraduate Students' Mental Models of the Environment: Are They Related to Environmental Affect and Behavior? *J. Environ. Educ.* **2014**, *46*, 23–40. [CrossRef]
29. Trillo, M. De la educación a distancia a la educación virtual. *Te Et.* **2009**, *4*, 303. [CrossRef]
30. De Amorim Soares, M.L.; Petarnella, L. Schooling for Sustainable Development: Autonomy, Citizenship and Social Justice in South America. In *Schooling for Sustainable Development in South America*; Springer: Dordrecht, The Netherlands, 2011; pp. 3–18.
31. Niño, A.C.M.; Romero, J.F.H. La formación ambiental en la educación superior:una revisión necesaria. *Luna Azul* **2014**, 186–206. [CrossRef]
32. Quiva, D.; Vera, L. Environmental Education as a Tool to Promote Sustainable Development. *Telos* **2010**, *12*, 378–394.

33. Leon-Fernandez, Y.; Gomera, A.; Antúnez, M.; Martínez-Escrich, B.; Villamandos, F.; Vaquero, M. Enhancing environmental management in universities through participation: The case of the University of Córdoba. *J. Clean. Prod.* **2018**, *172*, 4328–4337. [CrossRef]
34. Mitsch, W.J. What is ecological engineering? *Ecol. Eng.* **2012**, *45*, 5–12. [CrossRef]
35. Meyer, A. Does education increase pro-environmental behavior? Evidence from Europe. *Ecol. Econ.* **2015**, *116*, 108–121. [CrossRef]
36. Wright, T.S.A. Definitions and frameworks for environmental sustainability in higher education. *Int. J. Sustain. High. Educ.* **2002**, *15*, 105–120.
37. Tilbury, D. Higher Education for Sustainability: A Global Overview of Commitment and Progress. In *Higher Education in the World 4. Higher Education's Commitment to Sustainability: From Understanding to Action*; Global University Network for Innovation (GUNI), Ed.; Palgrave Macmillan: Barcelona, Spain, 2012; pp. 18–28.
38. Karatzoglou, B. An in-depth literature review of the evolving roles and contributions of universities to Education for Sustainable Development. *J. Clean. Prod.* **2013**, *49*, 44–53. [CrossRef]
39. Jahanbakhsh, A.; Pournik, M.; Nakhaee, A.; Sadighi, A.; Azadpour, M.; Emad, M. A Comparative Study of Engineering Education in Iran and USA: An Attitude Survey of Iranian Students Abroad. 2009, pp. 1–8. Available online: http://www.isee.ir/FileForDownload/files/76.pdf (accessed on 3 September 2020).
40. Ghaffari, S.; Talebbeydokhti, N. Status of Environmental Engineering Education in Various Countries in Comparison with the Situation in Iran. *Procedia Soc. Behav. Sci.* **2013**, *102*, 591–600. [CrossRef]
41. Tansel, B. Changing the Status Quo in Environmental Engineering Education in Response to Emerging Markets. *J. Prof. Issues Eng. Educ. Pract.* **2008**, *134*, 197–202. [CrossRef]
42. Rodríguez-Roda, I.; Castells, F.; Flotats, X.; Lema, J.; Tejero, I. Environmental engineering education in Spain. *Water Sci. Technol.* **2004**, *49*, 101–108. [CrossRef] [PubMed]
43. Nguyen, D.Q.; Pudlowski, Z.J. An Overview of Environmental Engineering Education in The Past Decade: A Global Perspective. In Proceedings of the 2nd WIETE Annual Conference on Engineering and Technology Education, Pattaya, Thailand, 25–28 January 2011; pp. 25–28.
44. Arboleda, I.F.M.; Páramo, P. La investigación en educación ambiental en América Latina: Un análisis bibliométrico. *Rev. Colomb. Educ.* **2014**, *1*, 55–72. [CrossRef]
45. Chawla, L.; Derr, V. The development of conservation behaviors in childhood and youth. *Oxford Handb. Environ. Conserv. Psychol.* **2012**. [CrossRef]
46. López, L.M.R.; Londoño, J.V.E.; de Jesús Arango Ruiz, A.; Molina-Benítez, J.-A.; Parodi, T.V.; Montaña, D.F.V. Educación para el desarrollo sostenible: Acercamientos desde una perspectiva colombiana. *Prod. Limpia* **2018**, *13*, 133–149. [CrossRef]
47. Fernando, G.S.H.; Eugenia, V.M.; Mauricio, A.C.P. *Estudios Sobre Medio Ambiente y Sostenibilidad: Una Mirada Desde Colombia*; Ediciones USTA: Bogotá, Colombia, 2018, ISBN 978-958-5471-12-2.
48. Kopnina, H. Neoliberalism, pluralism and environmental education: The call for radical re-orientation. *Environ. Dev.* **2015**, *15*, 120–130. [CrossRef]
49. Liu, S.-C. Environmental Education through Documentaries: Assessing Learning Outcomes of a General Environmental Studies Course. *Eurasia J. Math. Sci. Technol. Educ.* **2018**, *14*, 1371–1381. [CrossRef]
50. Ardoin, N.M.; Bowers, A.W.; Gaillard, E. Environmental education outcomes for conservation: A systematic review. *Boil. Conserv.* **2020**, *241*, 108224. [CrossRef]
51. Freidenfelds, D.; Kalnins, S.N.; Gusca, J. What does environmentally sustainable higher education institution mean? *Energy Procedia* **2018**, *147*, 42–47. [CrossRef]
52. Semerjian, L.; El-Fadel, M.; Zurayk, R.; Nuwayhid, I. Interdisciplinary Approach to Environmental Education. *J. Prof. Issues Eng. Educ. Pract.* **2004**, *130*, 173–181. [CrossRef]
53. Castellanos, P.M.A.; Dios, A.Q.; Ortegon, A.C. The lack of environmental education in the training of environmental engineers in Colombia. In *Proceedings of the SEFI 47th Annual Conference: Varietas Delectat. Complexity Is the New Normality, Proceedings*; European Society for Engineering Education (SEFI): Brussels, Belgium, 2020; pp. 70–82.
54. Ekpiken, W.E.; Ukpabio, G.U. Youth Empowerment in Higher Education for Sustainable Development of Developing Communities in Cross River State, Nigeria. *Int. Educ. Stud.* **2015**, *8*, 113–119. [CrossRef]
55. Bonnett, M. Sustainable development, environmental education, and the significance of being in place. *Curric. J.* **2013**, *24*, 250–271. [CrossRef]

56. Kopnina, H. Education for sustainable development (ESD): Exploring anthropocentric–ecocentric values in children through vignettes. *Stud. Educ. Eval.* **2014**, *41*, 124–132. [CrossRef]
57. Balza-Franco, V. Formulación y diseño de un modelo de vigilancia tecnológica curricular en programas de ingeniería en Colombia. *Rev. Educ. Super.* **2016**, *45*, 55–77. [CrossRef]
58. Barriga, F.D. Aproximaciones metodológicas al diseño curricular: Hacia una propuesta integral. *Tecnol. Comun. Educ.* **1993**, *21*, 19–39.
59. CNA; CESU. Acuerdo 03 de 2014: Por el cual se aprueban los Lineamientos para la Acreditación Institucional. *Cons. Nac. Acreditación Cons. Nac. Educ. Super.* **2014**, *32*. Available online: https://www.cna.gov.co/1741/articles-186370_acuerdo_03_2014.pdf (accessed on 3 September 2020).
60. Guan, Y. A generalized score confidence interval for a binomial proportion. *J. Stat. Plan. Inference* **2012**, *142*, 785–793. [CrossRef]
61. Rodríguez-Miranda, J.P.; García-Ubaque, C.A.; Garcia-Ubaque, J.C. Enfermedades transmitidas por el agua y saneamiento básico en Colombia. *Rev. Salud Pública* **2017**, *18*, 738. [CrossRef]
62. Hamalosmanoglua, M. The Place of Environmental Education in Science Education Curricula in Turkey. *Procedia Soc. Behav. Sci.* **2012**, *46*, 4839–4844. [CrossRef]
63. Shawe, R.; Horan, W.; Moles, R.; O'Regan, B. Mapping of sustainability policies and initiatives in higher education institutes. *Environ. Sci. Policy* **2019**, *99*, 80–88. [CrossRef]
64. Quelhas, O.L.; Lima, G.B.A.; Ludolf, N.V.E.; Meiriño, M.J.; Abreu, C.; Anholon, R.; Neto, J.V.; Rodrigues, L.S.G. Engineering education and the development of competencies for sustainability. *Int. J. Sustain. High. Educ.* **2019**, *20*, 614–629. [CrossRef]
65. Perpignan, C.; Baouch, Y.; Robin, V.; Eynard, B. Engineering education perspective for sustainable development: A maturity assessment of cross-disciplinary and advanced technical skills in eco-design. *Procedia CIRP* **2020**, *90*, 748–753. [CrossRef]
66. Mulder, K.; Segalas-Coral, J.; Ferrer-Balas, D. How to educate engineers for/in sustainable development. *Int. J. Sustain. High. Educ.* **2012**, *13*, 211–218. [CrossRef]
67. Bielefeldt, A.R. Incorporating a Sustainability Module into First-Year Courses for Civil and Environmental Engineering Students. *J. Prof. Issues Eng. Educ. Pract.* **2011**, *137*, 78–85. [CrossRef]

5. ARTÍCULO 2

From Environmental Education to Education for Sustainable Development in Higher Education: A Systematic Review

Resumen

En la educación en materia ambiental, existen dos corrientes predominantes en el mundo: la EA y la EDS. Esta última es la corriente actualmente promovida por Naciones Unidas para lograr que los países alcancen un desarrollo sostenible. Por su parte, la EA fue la primera corriente educativa que contaba con un enfoque ambiental. El propósito de esta revisión sistemática fue buscar evidencias sobre la efectividad de la migración de la EA a la EDS, así como su acogida por los investigadores y las universidades. Con lo anterior, se logró proporcionar un panorama global, donde se identificaron las regiones que optaban por cada modelo. Así mismo, se buscó determinar cuál de las dos corrientes tiene mayor aceptación dentro de la enseñanza de la ingeniería. Con los resultados obtenidos se identificó el avance de la EDS y el estado de la EA por regiones en el mundo. Fue posible categorizar las regiones geográficas que acogen las dos corrientes.

En este artículo se presenta una revisión sistemática que busca evidenciar si la migración de la EA a la EDS está siendo efectiva y acogida por parte de los investigadores y en especial por parte de las universidades. La revisión siguió los parámetros de PRISMA para revisiones sistemáticas, en total fueron analizados 198 artículos indexados en Scopus, Science Direct, ERIC y Scielo. Con los resultados se logró identificar el avance de la EDS y el estado de

arraigo de la EA, por regiones, en todo el mundo. Así mismo, se obtuvo el nivel en que se encuentran las universidades, en especial las ingenierías, respecto a la EDS.

5.1. Objetivos

Los objetivos que se propusieron en esta publicación fueron los siguientes:

- Analizar, mediante un análisis bibliométrico, la influencia de la década para la EDS, (entre los años 2005 y 2014), propuesta por la UNESCO, de la transición de la EA a la EDS.
- Identificar las regiones geográficas que orientan su enseñanza hacia la EA o la EDS, relacionándolo con las características económicas y sociales de cada región.
- Determinar la inclusión de la EDS en los currículos de grado de educación superior y su existencia dentro de la enseñanza de las ingenierías.

5.2. Metodología

La investigación siguió los criterios de calidad de PRISMA para revisiones sistemáticas y metaanálisis. Después de la aplicación de filtros, se analizaron un total 198 artículos indexados en Scopus, Science Direct, ERIC y Scielo. A continuación, se aplicó el marco de población, intervención, comparación, resultado y contexto (PICOC). La investigación se concentró en el periodo de tiempo desde 1987, cuando apareció el concepto de desarrollo sostenible, hasta la actualidad. Posteriormente, se definió como criterio el de las publicaciones completas de libros, capítulos de libro y artículos; así mismo, únicamente se consideraron los artículos publicados en idioma inglés y castellano.

En este estudio se plantearon las siguientes tres preguntas de investigación, enfocadas a la EDS y la EA:

1. ¿Se puede evidenciar la existencia de una transición de la EA a la EDS partir las propuestas de acoger este modelo por la ONU?

Esta pregunta abordó el avance de la EDS frente a su contraparte, la EA. Si las investigaciones en EA son mayores, teniendo en cuenta las propuestas de la ONU de acoger la EDS, podría indicar deficiencias en el proceso de divulgación de esta corriente. Si, por el contrario, a partir de las propuestas de la ONU, se está investigando más en la EDS, indicaría que es una apuesta acertada y, por lo tanto, aceptada por la comunidad científica.

2. ¿Se puede identificar una región geográfica donde se continúe investigando bajo un enfoque de EA que indique una resistencia a la transición a la EDS?

Con esta pregunta se buscó identificar qué regiones han avanzado más en la EDS, asumiendo que, a mayor investigación, mayor es la acogida de esta corriente, relacionándola con las características económicas y desarrollo de cada región.

3. ¿De qué manera se puede evidenciar la inclusión de la EDS en los currículos de grado de la educación superior y en particular en la enseñanza de las ingenierías?

En este caso, se buscó identificar las buenas prácticas de integración de la EDS en las universidades y si los futuros profesionales estarán alineados con el modelo de desarrollo sostenible.

5.3. Resultados

En el análisis realizado como parte de este estudio, fue posible categorizar las regiones geográficas por corrientes de enseñanza, ya sea por la EA o la EDS. Además, se logró definir las tendencias de investigación por periodos de tiempo y determinar la influencia de las políticas globales, como la denominada década para la EDS de la UNESCO.

5.4. Conclusiones

Una vez concluida la revisión sistemática, se encontró que algunas regiones del planeta están aún investigando y centrándose en la EA en lugar de la EDS, especialmente todo el continente americano. Por otro lado, se evidenció que la década de la EDS propuesta por la UNESCO tuvo un gran efecto en la cantidad de investigaciones realizadas sobre la EDS y el DS, pero después de dicho periodo, el número de publicaciones sobre EDS disminuyó considerablemente. Se constató que Europa es el continente que lidera en número de investigaciones a nivel mundial relacionadas con la EDS. Si bien se encontraron algunas evidencias de la inclusión de la EDS en la enseñanza de las ingenierías, resultan muy pocas si se comparan con el total de investigaciones que existen sobre este tema.

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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; Kopnina, 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-Analyzes" (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

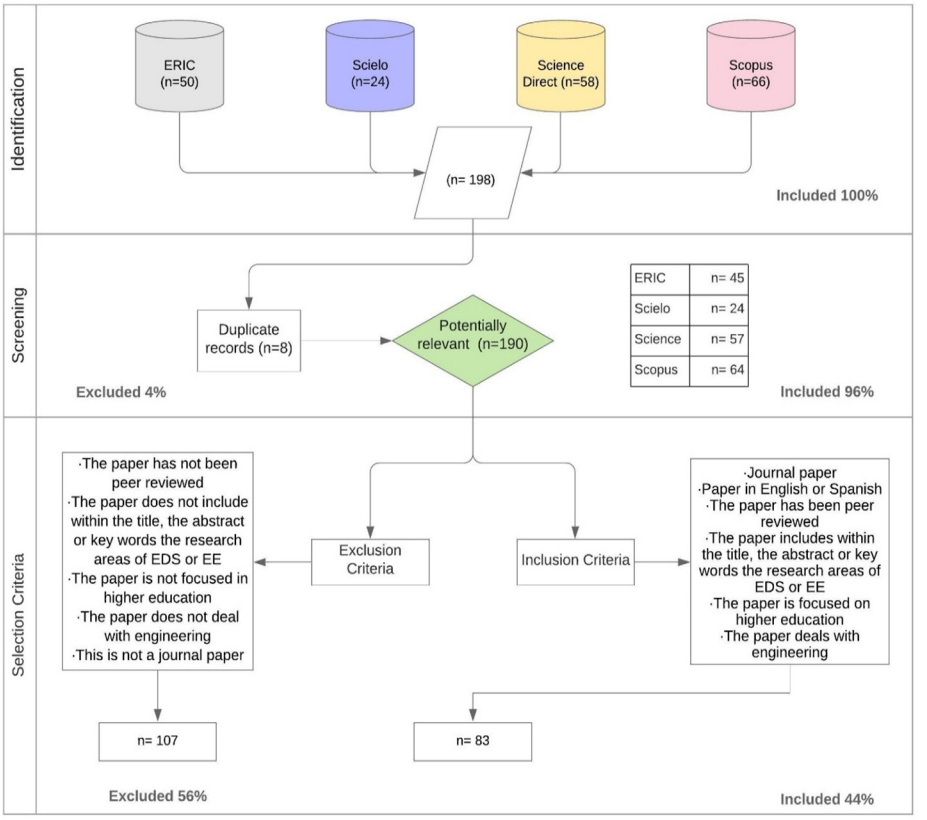

Figure 1.
Flow diagram of the methodological process adapted from the one suggested by PRISMA and related to ESD

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.

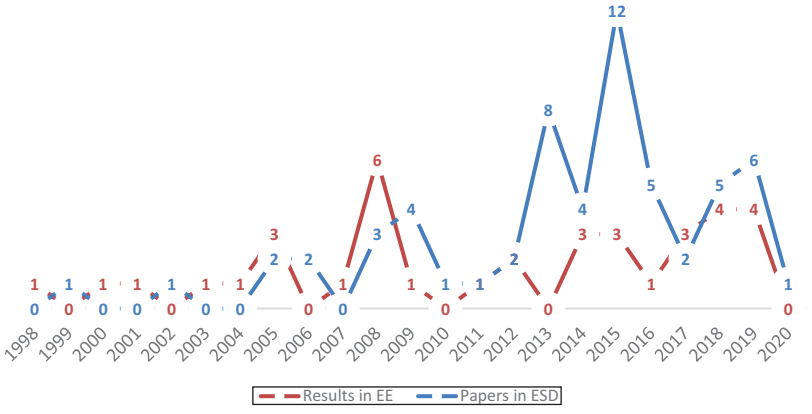

Figure 2.
Results in EE and ESD since 1987

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
n (total)	37	60
%	38%	62%
Mean	2	3
Mean in the decade for ESD (2005–2015)	1.82	3.55
n in the decade for ESD (2005–2015)	20	39
% in the decade for ESD (2005–2015)	34%	66%

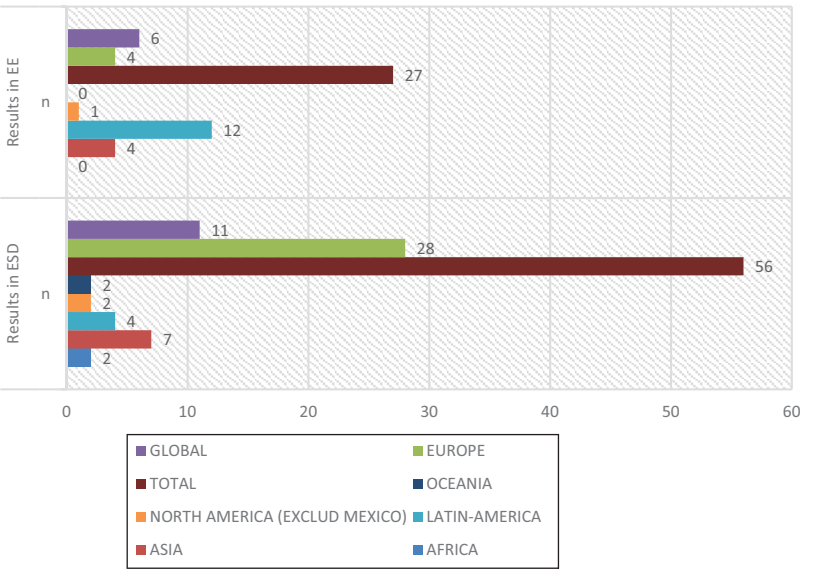

Figure 3. The ESD and EE results by geographic region

Title	Author	Paper about EE/ESD
Moving toward an ecologically sound society? Starting from green universities and environmental higher education	(Wang *et al.*, 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 *et al.*, 2015)	ESD
A study on impact of the UN decade of education for sustainable development on industrial engineering education	(Colombo *et al.*, 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 *et al.*, 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 *et al.*, 2016a)	ESD
Future sustainability scenarios for universities: moving beyond the United Nations decade of education for sustainable development	(Beynaghi *et al.*, 2016)	ESD
A proposal of a balanced scorecard for an environmental education program at universities	(de Andrade Guerra *et al.*, 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 *et al.*, 2005)
Global learning and education for sustainable development	(Brunold, 2005)
A center for excellence in education for sustainable development	(Dyer *et al.*, 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 *et al.*, 2008)
Revolutions and second-best solutions: education for sustainable development in higher education	(Cotton *et al.*, 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 *et al.*, 2013a)
Integration of education for sustainable development in the mechanical engineering curriculum	(Enelund *et al.*, 2013)
Developing and piloting a baselining tool for education for sustainable development and global citizenship (ESDGC) in Welsh higher education	(Glover *et al.*, 2013)
Education for sustainable development in higher education: state-of-the-art, barriers and challenges	(Fernández Sánchez *et al.*, 2014)
Education for sustainable development and quality assurance in universities in China and the Nordic countries: a comparative study	(Holm *et al.*, 2015)
Education for sustainable development through e-learning in higher education: experiences from Portugal	(Azeiteiro *et al.*, 2015)
Education for sustainable development in higher education: evaluating coherence between theory and praxis	(Amador *et al.*, 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 *et al.*, 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 *et al.*, 2017a)
Improving engineering education for sustainable development using concept maps and multivariate data analysis	(Svanström *et al.*, 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 *et al.*, 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 *et al.*, 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 *et al.*, 2015)
Environmental education and education for sustainable development in Romania. Teachers perceptions and recommendations	(ilovan *et al.*, 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 *et al.*, 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	(Diaz *et al.*, 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 Montaño 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 *et al.*, 2019)	EE
Enhancing education for sustainable development in environmental university programmers: a co-creation approach	(Perello-Marín *et al.*, 2018)	ESD
Educación para el desarrollo sostenible: acercamientos desde una perspectiva colombiana	(María *et al.*, 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 *et al.*, 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	(%)
Partially include ESD in Engineering	*19*	*23*
Asia	3	4
Europa	10	12
Global	3	4
Latin-America	1	1
Oceania	2	2
Include ESD in Engineering	*7*	*8*
Europa	3	4
Global	2	2
Latin-America	2	2
Total	33	40

Table 6.
ESD Publications about engineering education

Title	Authors
A centre for excellence in education for sustainable development	(Dyer *et al.*, 2006)
Implementing the United Nations decade on education for sustainable development in Latvian higher education	(Dyer *et al.*, 2006)
Embedding education for sustainable development in higher education: a case study examining common challenges and opportunities for undergraduate programs	(Jones *et al.*, 2008)
Revolutions and second-best solutions: education for sustainable development in higher education	(Cotton *et al.*, 2009)
A perspective on education for sustainable development: historical development of environmental education in Indonesia	(Cotton *et al.*, 2009)
Education for sustainable development: liberation or indoctrination? An assessment of faculty members' attitudes and classroom practices	(Qablan *et al.*, 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 *et al.*, 2015)
Education for sustainable development and quality assurance in universities in China and the Nordic countries: a comparative study	(Holm *et al.*, 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 *et al.*, 2015)
Education for sustainable development in higher education: evaluating coherence between theory and praxis	(Amador *et al.*, 2015b)
Catalysing change in higher education for sustainable development: A review of professional development initiatives for university educators	(Mulà *et al.*, 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 *et al.*, 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 *et al.*, 2015)

Table 7.
Publications that partially involve ESD in engineering teaching

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.

References

Acosta Castellanos, P.M., Queiruga-Dios, A., Encinas, A.H. and Acosta, L.C. (2020), "Environmental education in environmental engineering: Analysis of the situation in Colombia and Latin America", *Sustainability*, Vol. 12 No. 18, p. 7239.

Aguado, A.B. (2012), "La financiación de la educación en áfrica subsahariana hoy", *Foro de Educación, 28 October*, Vol. 10 No. 14, pp. 41-54.

Aguilar, O.M. (2018), "Examining the literature to reveal the nature of community EE/ESD programs and research", *Environmental Education Research*, Routledge, 2 January.

Amador, F., Martinho, A.P., Bacelar-Nicolau, P., Caeiro, S. and Oliveira, C.P. (2015a), "Education for sustainable development in higher education: evaluating coherence between theory and praxis", assessment and evaluation in higher education", *Assessment and Evaluation in Higher Education*, Vol. 40 No. 6, pp. 867-882.

Amador, F., Martinho, A.P., Bacelar-Nicolau, P., Caeiro, S. and Oliveira, C.P. (2015b), "Education for sustainable development in higher education: evaluating coherence between theory and praxis", *Assessment and Evaluation in Higher Education*, Vol. 40 No. 6, pp. 867-882.

De Andrade Guerra, J.B.S.O., Garcia, J., de Andrade Lima, M., Barbosa, S.B., Heerdt, M.L. and Berchin, I. I. (2018), "A proposal of a balanced scorecard for an environmental education program at universities", *Journal of Cleaner Production*, Vol. 172, pp. 1674-1690.

Ardoin, N.M., Bowers, A.W. and Gaillard, E. (2020), "Environmental education outcomes for conservation: a systematic review", *Biological Conservation*, Vol. 241, p. 108224.

Azeiteiro, U.M., Bacelar-Nicolau, P., Caetano, F.J.P. and Caeiro, S. (2015), "Education for sustainable development through e-learning in higher education: experiences from Portugal", *Journal of Cleaner Production*, Vol. 106, pp. 308-319.

Bagoly-Simó, P., Hemmer, I. and Reinke, V. (2018), "Training ESD change agents through geography: Designing the curriculum of a master's program with emphasis on education for sustainable development (ESD)", *Journal of Geography in Higher Education*, Vol. 42 No. 2, pp. 174-191.

Balls, E. (2016), "Analysing key debates in education and sustainable development in relation to ESD practice in Viet Nam", *International Journal of Development Education and Global Learning*, Vol. 8 No. 1, pp. 21-37.

Barth, M. and Rieckmann, M. (2012), "Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective", *Journal of Cleaner Production*, Vol. 26, pp. 28-36.

Berdugo Silva, N.C. and Montaño Renuma, W.Y. (2017), "La educación ambiental en las instituciones de educación superior públicas acreditadas en Colombia", *Revista Científica General José María Córdova*, Vol. 15 No. 20, available at: https://doi.org/10.21830/19006586.178

Bessant, S.E.F. and Robinson, Z.P. (2019), "Rating and rewarding higher education for sustainable development research within the marketised higher education context: experiences from English universities", *Environmental Education Research*, Vol. 25 No. 4, pp. 548-565.

Beynaghi, A., Trencher, G., Moztarzadeh, F., Mozafari, M., Maknoon, R. and Filho, W. (2016), "Future sustainability scenarios for universities: moving beyond the united nations decade of education for sustainable development", *Journal of Cleaner Production*, Vol. 112, pp. 3464-3478.

Biasi, P., Ferrini, S., Borghesi, S., Rocchi, B. and Di Matteo, M. (2019), "Enriching the italian genuine saving with water and soil depletion: National trends and regional differences", *Ecological Indicators*, Vol. 107, available at: https://doi.org/10.1016/j.ecolind.2019.105573

Bleck, S., Bullinger, M., Lude, A. and Schaal, S. (2012), "Electronic mobile devices in environmental education (EE) and education for sustainable development (ESD) – evaluation of concepts and potentials", *Procedia - Social and Behavioral Sciences*, Vol. 46, pp. 1232-1236.

Bongaarts, J. (2016), "Development: Slow down population growth", Nature, Nature Publishing Group, 24 February.

Bonnett, M. (2013), "Sustainable development, environmental education, and the significance of being in place", *The Curriculum Journal*, Vol. 24 No. 2, pp. 250-271.

Briggs, L., Trautmann, N.M. and Fournier, C. (2018), "Environmental education in latin american and the caribbean: the challenges and limitations of conducting a systematic review of evaluation and research", *Environmental Education Research*, Vol. 24 No. 12, pp. 1631-1654.

Brunold, A.O. (2005), "Global learning and education for sustainable development", *Higher Education in Europe*, Vol. 30 Nos 3/4, pp. 295-306.

Burmeister, M. and Eilks, I. (2013), "An understanding of sustainability and education for sustainable development among German student teachers and trainee teachers of chemistry", Science Education International.

Bush, D., Sieber, R., Seiler, G. and Chandler, M. (2017), "University-level teaching of anthropogenic global climate change (AGCC) via student inquiry", *Studies in Science Education*, Vol. 53 No. 2, pp. 113-136.

Callejas Restrepo, M.M., Sáenz Zapata, O., Plata Rangel, Á.M., Holguín Aguirre, M.T. and Mora Penagos, W.M. (2019), "El compromiso ambiental de instituciones de educación superior en Colombia", *Praxis and Saber*, available at: https://doi.org/10.19053/22160159.v9.n21.2018.8928

Castellanos, P.M.A., Dios, A.Q., Ortegon, A.C. (2020), ""The lack of environmental education in the training of environmental engineers in Colombia", SEFI 47th Annual Conference: Varietas Delectat. . . Complexity Is the New Normality, Proceedings, European Society for Engineering Education (SEFI), pp. 70-82.

Colombo, C., Alves, A., Moreira, F. and Van Hattum-Janssen, N. (2015), "A study on impact of the UN decade of education for sustainable development on industrial engineering education", *Direccion y Organizacion*, Vol. 56, pp. 4-9.

Colón, A. (2016), "El efecto del currículo oculto de educación ambiental en estudiantes de educación superior", *Revista de Investigación*, Vol. 40 No. 88, pp. 166-175.

Cotton, D., Bailey, I., Warren, M. and Bissell, S. (2009), "Revolutions and second-best solutions: Education for sustainable development in higher education", *Studies in Higher Education*, Vol. 34 No. 7, pp. 719-733.

Crossley, M. and Sprague, T. (2014), "Education for sustainable development: Implications for small island developing states (SIDS)", *International Journal of Educational Development*, Vol. 35, pp. 86-95.

Díaz, E., Martínez, E. and Flóres, M. (2008), "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", *Paradigma*, Vol. 9 No. 2, pp. 10-23.

Dyer, A., Selby, D. and Chalkley, B. (2006), "A Centre for excellence in education for sustainable development", *Journal of Geography in Higher Education*, *Taylor and Francis Group*, Vol. 30 No. 2, pp. 307-312.

Egelund Holgaard, J., Hadgraft, R., Kolmos, A. and Guerra, A. (2016b), "Strategies for education for sustainable development - Danish and Australian perspectives", *Journal of Cleaner Production*, Vol. 112, pp. 3479-3491.

Ekpiken, W.E. and Ukpabio, G.U. (2015), "Youth empowerment in higher education for sustainable development of developing communities in Cross River state, Nigeria", *International Education Studies*, Vol. 8 No. 9, pp. 113-119.

El-Jardali, F., Ataya, N. and Fadlallah, R. (2018), "Changing roles of universities in the era of SDGs: Rising up to the global challenge through institutionalising partnerships with governments and communities", *Health Research Policy and Systems*, Vol. 16 No. 1, p. 38.

Enelund, M., Knutson Wedel, M., Lundqvist, U. and Malmqvist, J. (2013), "Integration of education for sustainable development in the mechanical engineering curriculum", *Australasian Journal of Engineering Education*, Vol. 19 No. 1, pp. 51-62.

Ferguson, T. (2020), "Environmental and sustainability education in the caribbean: crucial issues, critical imperatives", *Environmental Education Research*, Vol. 26 No. 6, pp. 763-771.

Fernández-Manzanal, R., Serra, L.M., Morales, M.J., Carrasquer, J., Rodríguez-Barreiro, L.M., Valle,], J., [. and del Murillo, M.B. (2015), "Environmental behaviours in initial professional development and their relationship with university education", *Journal of Cleaner Production*, Vol. 108, pp. 830-840.

Fernández Sánchez, G., Bernaldo, M.O., Castillejo, A. and Manzanero, A.M. (2014), "Education for sustainable development in higher education: state-of-the-art, barriers, and challenges", *Higher Learning Research Communications*, Vol. 4 No. 3, pp. 3-11.

Filho, W.L., Manolas, E. and Pace, P. (2015), "The future we want key issues on sustainable development in higher education after rio and the un decade of education for sustainable development", *International Journal of Sustainability in Higher Education*, Vol. 16 No. 1, pp. 112-129.

Foo, K.Y. (2013), "A vision on the role of environmental higher education contributing to the sustainable development in Malaysia", *Journal of Cleaner Production*, Vol. 61, pp. 6-12.

García, M. and Ruiz Morón, D. (2008), "Educere La revista venezolana de educación., educere", Vol. 12 Vol. Univ. de Los Andes, available at: http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1316-49102008000300009&lng=es&nrm=iso&tlng=es

Glover, A., Jones, Y., Claricoates, J., Morgan, J. and Peters, C. (2013), "Developing and piloting a baselining tool for education for sustainable development and global citizenship (ESDGC) in welsh higher education", *Innovative Higher Education*, Vol. 38 No. 1, pp. 75-86.

González-Gaudiano, E.J. (2016), "ESD: Power, politics, and policy: 'tragic optimism' from latin america", *The Journal of Environmental Education*, Vol. 47 No. 2, pp. 118-127.

Grabovska, R. and Grabowski, J. (2009), "Implementing the united nations decade on education for sustainable development in latvian higher education", *Journal of Teacher Education for Sustainability*, Vol. 11 No. 1, pp. 18-30.

Grau, J.B., Tarquis, A.M., Martín-Sotoca, J.J. and Antón, J.M. (2019), "High level education on integrated water resources management for sustainable development", *Journal of Technology and Science Education*, Vol. 9 No. 3, pp. 2019-2028.

Gupta, S., Kumar Yadav, S. and Saini, S. (2011), "Innovative approaches for promoting environmental education in India", *The IIOAB Journal*, Vol. 2 No. 1, p. 35.

Hallinger, P. and Nguyen, V.T. (2020), "Mapping the landscape and structure of research on education for sustainable development: a bibliometric review", *Sustainability*, MDPI AG, Vol. 12 No. 5, p. 1947.

Hola, A., Imfadi, R. and Tareef, A. (2009), "Teaching for sustainable development in higher education institutions: University of Jordan as a case study", *College Student Journal*, Vol. 43 No. 4, pp. 1287-1305.

Holm, T., Sammalisto, K. and Vuorisalo, T. (2015), "Education for sustainable development and quality assurance in universities in China and the nordic countries: a comparative study", *Journal of Cleaner Production*, Vol. 107, pp. 529-537.

Hursh, D., Henderson, J. and Greenwood, D. (2015), "Environmental education in a neoliberal climate", *Environmental Education Research*, Vol. 21 No. 3, pp. 299-318.

Hyde, R.A. and Karney, B.W. (2001), "Environmental education research: Implications for engineering education", *Journal of Engineering Education*, Vol. 90 No. 2, pp. 267-275.

Ilovan, O.R., Dulamă, M.E. and Havadi-Nagy, K.X. (2019), "Environmental education and education for sustainable development in romania. Teachers' perceptions and recommendations (II)", *Romanian Review of Geographical Education*, Vol. 8 No. 2, pp. 21-37.

Iyer, V.G. (2015), "Education coupled with entrepreneurial process approach towards sustainable development", *Procedia - Social and Behavioral Sciences*, Vol. 177, pp. 147-161.

Johnston, R. (2011), "Science education and education for citizenship and sustainable development", *Collected Essays on Learning and Teaching*, Vol. 4, p. 107.

Jones, P., Trier, C.J. and Richards, J.P. (2008), "Embedding education for sustainable development in higher education: a case study examining common challenges and opportunities for undergraduate programmes", *International Journal of Educational Research*, Vol. 47 No. 6, pp. 341-350.

Kasimov, N.S., Malkhazova, S.M. and Romanova, E.P. (2005), "Environmental education for sustainable development in russia", *Journal of Geography in Higher Education*, Vol. 29 No. 1, pp. 49-59.

Kopnina, H. (2014), "Education for sustainable development (ESD): exploring anthropocentric–ecocentric values in children through vignettes", *Studies in Educational Evaluation*, Vol. 41, pp. 124-132.

Kopnina, H. (2015), "Neoliberalism, pluralism and environmental education: the call for radical re-orientation", *Environmental Development*, Vol. 15, pp. 120-130.

Lemos, M.C., Arnott, J.C., Ardoin, N.M., Baja, K., Bednarek, A.T., Dewulf, A., Fieseler, C., *et al.* (2018), "To co-produce or not to co-produce", *Nature Sustainability*, Vol. 1 No. 12.

Litzner Ordóñez, L.I. and Rieß, W. (2019), "Education for sustainable development in the context of higher education in Bolivia. Perceptions of university professors", *Teoria de La Educacion*, available at: https://doi.org/10.14201/teri.19037

Liu, S.C. (2018), "Environmental education through documentaries: Assessing learning outcomes of a general environmental studies course", *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 14 No. 4, pp. 1371-1381.

Marcinkowski, T. and Reid, A. (2019), "Reviews of research on the attitude–behavior relationship and their implications for future environmental education research", Environmental Education Research, Routledge, 3 April.

María, L., López, R., Victoria, J., Londoño, E., De Jesús, Á., Ruiz, A. and Andrés Molina Benítez, J. *et al.* (2018), "Education for sustainable development: approaches from a colombian perspective", *Producción + Limpia*, Vol. 13 No. 2, pp. 133-149.

Marouli, C. and Duroy, Q. (2019), "Reflections on the transformative power of environmental education in contemporary societies: Experience from two college courses in Greece and the USA", *Sustainability*, Vol. 11 No. 22, p. 6465.

McConnon, R. (2020), "Measures to facilitate the scale-up of education for sustainable development in higher education", *International Journal of Sustainable Society*, Vol. 12 No. 1, pp. 36-50.

Milutinović, S. and Nikolić, V. (2014), "Rethinking higher education for sustainable development in serbia: an assessment of copernicus charter principles in current higher education practices", *Journal of Cleaner Production*, Vol. 62, pp. 107-113.

Moher, D., Liberati, A., Tetzlaff, J. and Altman, D.G. (2009), "Preferred reporting items for systematic reviews and Meta-Analyses: the PRISMA statement", *PLoS Medicine*, Vol. 6 No. 7, pp. e1000097.

Molano Niño, A.C. and Herrera Romero, J.F. (2014), "La formación ambiental en la educación superior:una revisión necesaria", *Luna Azul*, No. 39, available at: https://doi.org/10.17151/luaz.2014.39.12

Muftakhova, S.I., Blonskaya, L.N., Sabirzyanov, I.G., Konashova, S.I. and Timeryanov, A.S. (2020), "Age dynamics of growth and development of populus pyramidalis in city planting", *International Journal of Environmental Studies*, Vol. 78 No. 1, pp. 1-10.

Mulà, I., Tilbury, D., Ryan, A., Mader, M., Dlouhá, J., Mader, C., Benayas, J., *et al.* (2017a), "Catalysing change in higher education for sustainable development: a review of professional development initiatives for university educators", *International Journal of Sustainability in Higher Education*, Vol. 18 No. 5, available at: https://doi.org/10.1108/IJSHE-03-2017-0043

Mulà, I., Tilbury, D., Ryan, A., Mader, M., Dlouhá, J., Mader, C., Benayas, J., *et al.* (2017b), "Catalysing change in higher education for sustainable development: a review of professional development initiatives for university educators", *International Journal of Sustainability in Higher Education*, Vol. 18 No. 5, pp. 798-820.

Nasibulina, A. (2015), "Education for sustainable development and environmental ethics", *Procedia - Social and Behavioral Sciences*, Vol. 214, pp. 1077-1082.

Nomura, K. (2009), "A perspective on education for sustainable development: Historical development of environmental education in Indonesia", *International Journal of Educational Development*, Vol. 29 No. 6, pp. 621-627.

Nousheen, A., Yousuf Zai, S.A., Waseem, M. and Khan, S.A. (2020), "Education for sustainable development (ESD): Effects of sustainability education on pre-service teachers' attitude towards sustainable development (SD)", *Journal of Cleaner Production*, Vol. 250, p. 119537.

Owens, T.L. (2017), "Higher education in the sustainable development goals framework", *European Journal of Education*, Vol. 52 No. 4, available at: https://doi.org/10.1111/ejed.12237

Perello-Marín, M., Ribes-Giner, G. and Pantoja Díaz, O. (2018), "Enhancing education for sustainable development in environmental university programmes: a Co-Creation approach", *Sustainability*, Vol. 10 No. 2, p. 158.

Qablan, A.M., Al-Ruz, J.A., Khasawneh, S. and Al-Omari, A. (2009), "Education for sustainable development: Liberation or indoctrination? An assessment of faculty members' attitudes and classroom practices", *International Journal of Environmental and Science Education*.

Radinger-Peer, V. and Pflitsch, G. (2017), "The role of higher education institutions in regional transition paths towards sustainability: the case of linz (Austria)", *Review of Regional Research*, Vol. 37 No. 2, pp. 161-187.

Rendón López, L.M., Londoño, J.V.E., Ruiz, Á.D.J.A., Benítez, J.A.M., Parodi, T.V. and Montaña, D.F.V. (2018), "Education for sustainable development: Approaches froma colombian perspective", produccion y limpia", *Corporacion Universitaria Lasallista*, Vol. 13 No. 2, pp. 133-149.

Richter, B.W. and De Sousa, L.O. (2019), "The implementation of environmental education to promote sustainability: an overview of the processes and challenges. International journal of sustainable development and world ecology, 26", *International Journal of Sustainable Development and World Ecology*, Vol. 26 No. 8, pp. 721-731.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., *et al.* (2009), "A safe operating space for humanity", *Nature*, Nature Publishing Group, 24 September.

Romero, H. Nick, A. (2007), "Modelo didáctico Para la enseñanza de la educación ambiental en la educación superior venezolana", Revista de . . ..

Scheffer, M., Carpenter, S., Foley, J.A., Folke, C. and Walker, B. (2001), "Catastrophic shifts in ecosystems", *Nature*, Vol. 413 No. 6856.

Semerjian, L., El-Fadel, M., Zurayk, R. and Nuwayhid, I. (2004), "Interdisciplinary approach to environmental education", *Journal of Professional Issues in Engineering Education and Practice*, Vol. 130 No. 3, pp. 173-181.

Sepulveda, L. (2012), "La educación ambiental en el nivel educativo superior de manizales", *Luna Azul*, Vol. 34 No. 2, pp. 50-65.

Shephard, K., Harraway, J., Lovelock, B., Mirosa, M., Skeaff, S., Slooten, L., Strack, M., *et al.* (2015), "Seeking learning outcomes appropriate for 'education for sustainable development' and for higher education", *Assessment and Evaluation in Higher Education*, Vol. 40 No. 6, pp. 855-866.

Sherren, K. (2008), "Higher environmental education: Core disciplines and the transition to sustainability the transition to sustainability", *Australasian Journal of Environmental Management*, *Taylor and Francis Group*, Vol. 15 No. 3, pp. 190-196.

Sims, L. and Falkenberg, T. (2013), "Developing competencies for education for sustainable development: a case study of Canadian faculties of education", *International Journal of Higher Education*, Vol. 2 No. 4, available at: https://doi.org/10.5430/ijhe.v2n4p1

Soria, B.R., Bella, J.M.P., Hernández, J.D., Suñén, E.C. and Del Coz Díaz, J.J. (2013), "Education for sustainable development: Methodology and application within a construction course", *Journal of Professional Issues in Engineering Education and Practice*, Vol. 139 No. 1, pp. 72-79.

Sosa, S.B., Isaac-Márquez, R., Eastmond, A., Ayala, M.E. and Arteaga, M.A. (2010), "Educación superior y cultura ambiental en el sureste de méxico", *Universidad y ciencia Scielo*, Vol. 26, pp. 33-49.

Sprenger, S. and Nienaber, B. (2018), "(education for) sustainable development in geography education: review and outlook from a perspective of Germany", *Journal of Geography in Higher Education*, Vol. 42 No. 2, available at: https://doi.org/10.1080/03098265.2017.1379057

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O. and Ludwig, C. (2015), "The trajectory of the anthropocene: the great acceleration", *The Anthropocene Review*, Vol. 2 No. 1, pp. 81-98.

Stepanskaya, T.M., Chernyaeva, I.V. and Naumova, V.I. (2016), "Master's program module 'environmental issues - Decision making experience' as precondition for implementation of education for sustainable development for professional training of teachers", *International Journal of Environmental and Science Education*.

Stevenson, R.B. (2007), "Schooling and environmental education: contradictions in purpose and practice", *Environmental Education Research*, Vol. 13 No. 2, pp. 139-153.

Svanström, M., Sjöblom, J., Segalàs, J. and Fröling, M. (2018), "Improving engineering education for sustainable development using concept maps and multivariate data analysis", *Journal of Cleaner Production*, Vol. 198, pp. 530-540.

Takeuchi, K. and Aginam, O. (2011), "Sustainability challenges and opportunities in africa", *Sustainability Science*, Springer, 23 December.

Toomey, A.H., Knight, A.T. and Barlow, J. (2017), "Navigating the space between research and implementation in conservation", *Conservation Letters*, Vol. 10 No. 5, pp. 619-625.

Tovar-Gálvez, J.C. (2017), "Pedagogía ambiental y didáctica ambiental: tendencias en la educación superior", *Revista Brasileira de Educação*, Vol. 22 No. 69, pp. 519-538.

UNESCO (1977), "The Tbilisi declaration: Intergovernmental conference", USSR Tbilisi.

UNESCO (2017), "Education for sustainable development goals: Learning objectives. Education for sustainable development. The global education 2030 agenda", available at: www.unesco.org/open-access/terms-%0Ahttp://www.unesco.org/open-access/terms-use-ccbysa-en (accessed 11 June 2020).

Valeron, N. (2008), "Environmental education in higher education institutions in Bolivar state, Venezuela", *Revista de Pedagogía*, Vol. 29 No. 85, pp. 36-45.

Vann, J., Pacheco, P. and Motloch, J. (2006), "Cross-cultural education for sustainability: development of an introduction to sustainability course", *Journal of Cleaner Production*, Vol. 14 No. 9-11, pp. 900-905.

Vargas, V.R., Lawthom, R., Prowse, A., Randles, S. and Tzoulas, K. (2019), "Implications of vertical policy integration for sustainable development implementation in higher education institutions", *Journal of Cleaner Production*, Vol. 235, pp. 733-740.

Velazquez, L.E., Munguia, N.E. and Romo, M.A. (1999), "Education for sustainable development: the engineer of the 21st century", *European Journal of Engineering Education*, Vol. 24 No. 4, pp. 359-370.

Wals, A.E.J. (2014), "Sustainability in higher education in the context of the un DESD: a review of learning and institutionalization processes", *Journal of Cleaner Production*, Elsevier, Vol. 62, pp. 8-15.

WalsArjen, E.J. (2012), "United nations decade of education for sustainable development (shaping the education of tomorrow: 2012 Full-Length report on the UN decade of education for sustainable development DESD monitoring and evaluation-2012 UNESCO education sector".

Wang, Y., Shi, H., Sun, M., Huisingh, D., Hansson, L. and Wang, R. (2013), "Moving towards an ecologically sound society? Starting from green universities and environmental higher education", *Journal of Cleaner Production*, Vol. 61, pp. 1-5.

West, S.E. (2015), "Understanding participant and practitioner outcomes of environmental education", *Environmental Education Research*, Vol. 21 No. 1, pp. 45-60.

Westerman, J.H., Westerman, J.W. and Whitaker, B.G. (2016), "Does social justice knowledge matter? Education for sustainable development and student attitudes", *Environment, Development and Sustainability*, Vol. 18 No. 2, available at: https://doi.org/10.1007/s10668-015-9665-7

Yan, Y., Zheng, X., Wang, S., Yang, G. and Zhang, J. (2019), "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)", *Ekoloji*, Vol. 28 No. 107, pp. 4711-4718.

Yanarella, E.J. (1999), "Local sustainability programmes in comparative perspective: Canada and the USA", *Local Environment*, Vol. 4 No. 2, pp. 209-223.

Yuan, X. and Zuo, J. (2013), "A critical assessment of the higher education for sustainable development from students' perspectives – a chinese study", *Journal of Cleaner Production*, Vol. 48, pp. 108-115.

Zoran, T. (2015), "Analysis of the impact of public education expenditure on economic growth of european union and BRICS", *Economic Analysis*, Vol. 48 No. 1–2, pp. 19-38.

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6. ARTÍCULO 3

Education for Sustainable Development (ESD): an example of curricular inclusion in environmental engineering in Colombia

Resumen

Este trabajo presentó un estudio de caso cuyo eje central fue la inclusión de una asignatura de educación de desarrollo sostenible en el plan de estudios de la carrera de ingeniería ambiental de la Universidad Santo Tomás de Colombia (USTA). Este estudio se basa en un diagnóstico desarrollado a partir de una encuesta realizada a 70 estudiantes de la USTA y 43 profesores de 13 universidades que ofrecen titulaciones de grado en ingeniería ambiental en Colombia. Se realizó una revisión curricular que demostró, efectivamente, la falta de inclusión de la EDS en las titulaciones universitarias. Una vez identificado el problema, se propuso una asignatura sobre EDS fundamentada en los propositos del desarrollo sostenible. Después de incluir la asignatura en el plan de estudios, se evaluó la aceptación de quienes la habían cursado frente a otros alumnos que no habían hecho. Esta investigación buscó brindar una manera efectiva de incluir la EDS en ingeniería ambiental. Adicionalmente, uno de los resultados relevantes incluyó la identificación de una brecha en el conocimiento del DS de profesores de ingeniería ambiental. Además, se encontró que los estudiantes estaban más capacitados en EA que en DS. Sin embargo, la incorporación de la EDS contribuyó a una mejor comprensión del DS.

6.1. Objetivos

Los objetivos propuestos en esta investigación fueron los siguientes:

- Determinar el estado del conocimiento de la EDS de profesores y estudiantes de ingeniería ambiental en Colombia.
- Evaluar las posibilidades de actualización curricular para la inclusión de la EDS como asignatura dentro del plan de estudios de una carrera de ingeniería ambiental.
- Evaluar la efectividad de la inclusión de una asignatura de EDS dentro del currículo de una carrera de ingeniería ambiental.

6.2. Metodología

Para esta investigación se establecieron tres fases con el fin de lograr la integración de la EDS en la ingeniería ambiental y llevar a cabo una renovación curricular acorde a las necesidades actuales. La primera fase que se consideró fue el estado de conocimiento de los estudiantes y profesores en el área de la EDS. En esta etapa se evaluó el currículo de la carrera de grado de ingeniería ambiental de la Universidad Santo Tomás. La segunda fase fue la inclusión de una asignatura de EDS en el currículo de ingeniería ambiental y su impartición durante un semestre lectivo. La tercera fase considerada fue la evaluación de la efectividad de dicha asignatura, mediante la aplicación de encuestas a estudiantes y profesores.

6.3. Resultados

Las encuestas iniciales a profesores y estudiantes evidenciaron un desconocimiento generalizado sobre la EDS, así como la confusión que existe en conceptos como protección y desarrollo, o conservación y sostenibilidad, entre otros. Por otro lado, los docentes, y en especial los estudiantes, instan a la preparación en temas relacionados con la EDS, puesto que constatan la necesidad de formación.

En lo que respecta a la evaluación curricular, los resultados corresponden a los hallazgos que se muestran en el Artículo 2 de esta tesis. En dicha publicación, se apreció una gran carga de la EA en los currículos y la escasez de todo lo relacionado con la EDS en Latinoamérica. Finalmente, la inclusión de una asignatura de EDS dentro del plan de estudios facilitó la comprensión de conceptos y la relación de corresponsabilidad de la ingeniería con el DS. La opinión generalizada de los estudiantes es que la asignatura de EDS debe ser parte del plan de estudios.

6.4. Conclusiones

Con esta investigación se propuso una solución a la falta de conocimiento de los estudiantes y profesores de ingeniería ambiental de la USTA con respecto al DS. Si bien la propuesta es la adición de una nueva materia en el plan de estudios, esta no debe ser la única opción dentro de un programa de educación superior, puesto que se busca una solución generalizada a toda la población estudiantil. Sin embargo, la inclusión de una asignatura parece ser la forma más rápida y sencilla de cambiar la forma en que se enseña la EDS y se incorpora a los planes de estudio.

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Article

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.

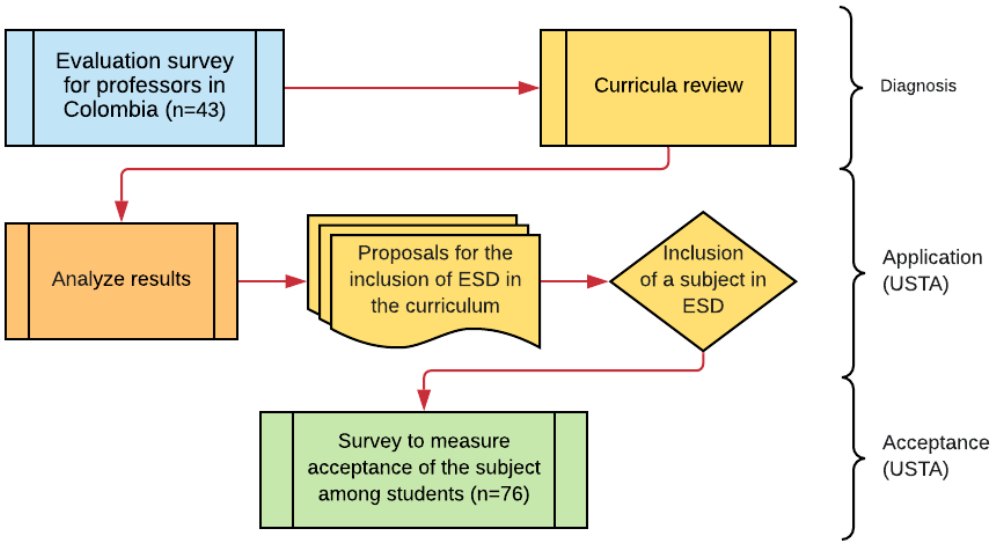

Figure 1. Methodological summary.

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.

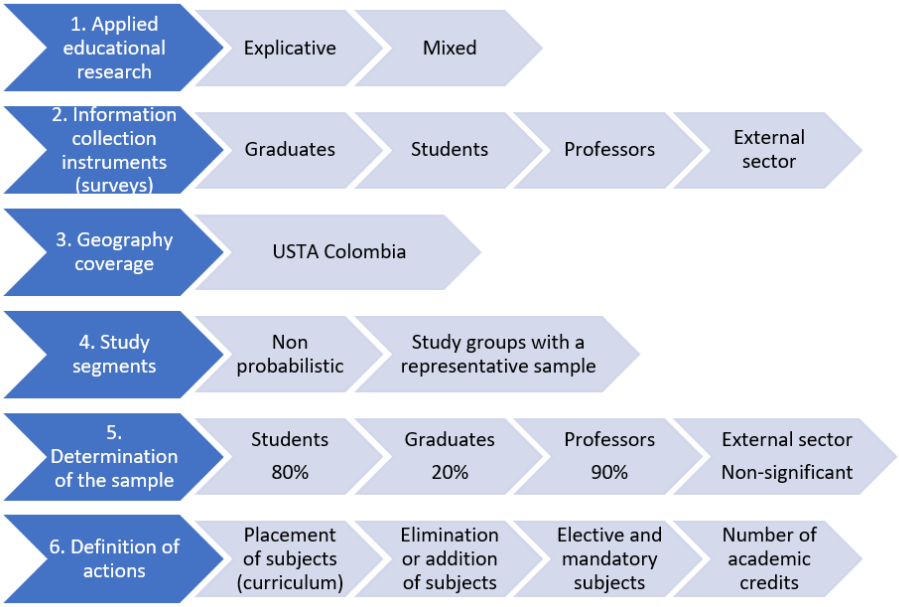

Figure 2. The USTA curricular evaluation model is applied to the environmental engineering undergraduate degree.

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.

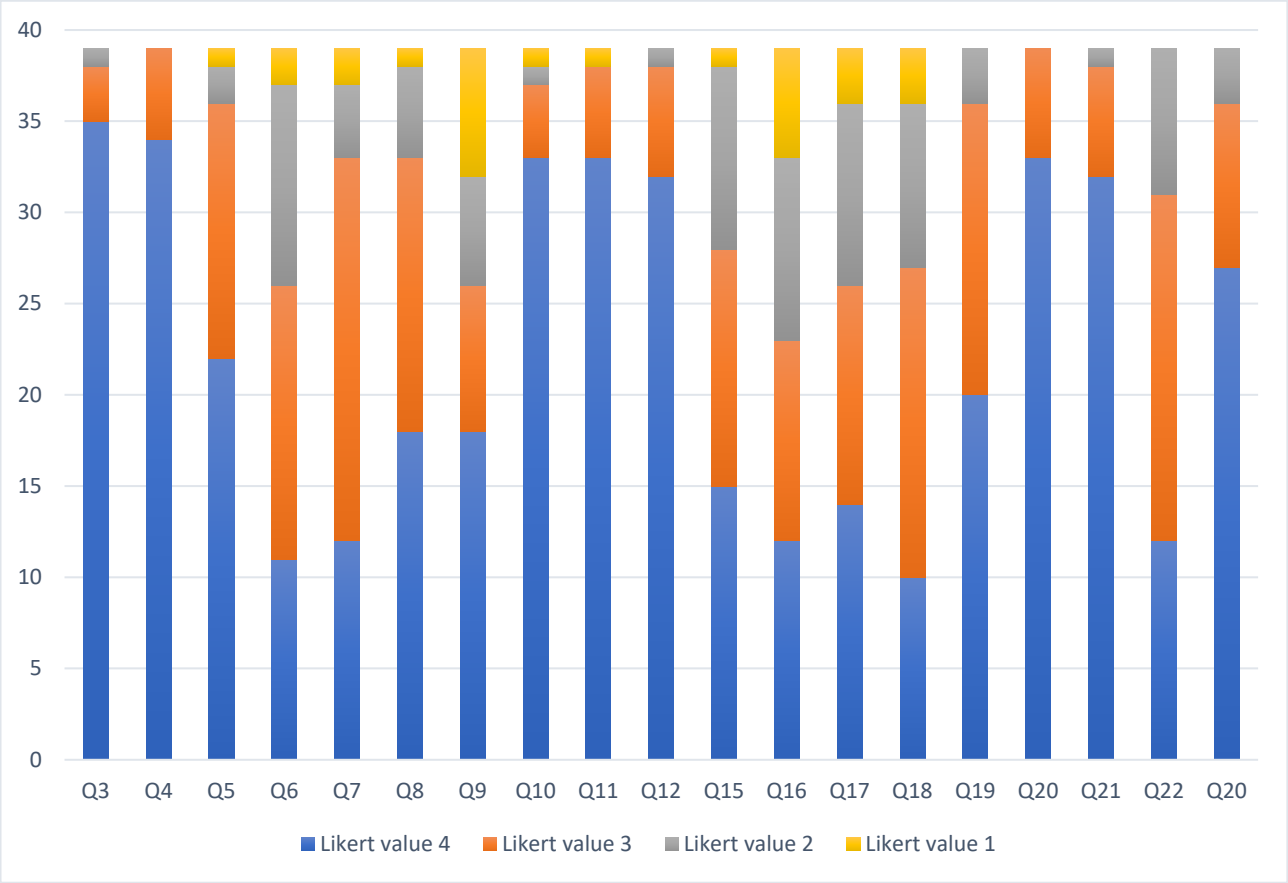

Figure 3. Professors' responses.

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].

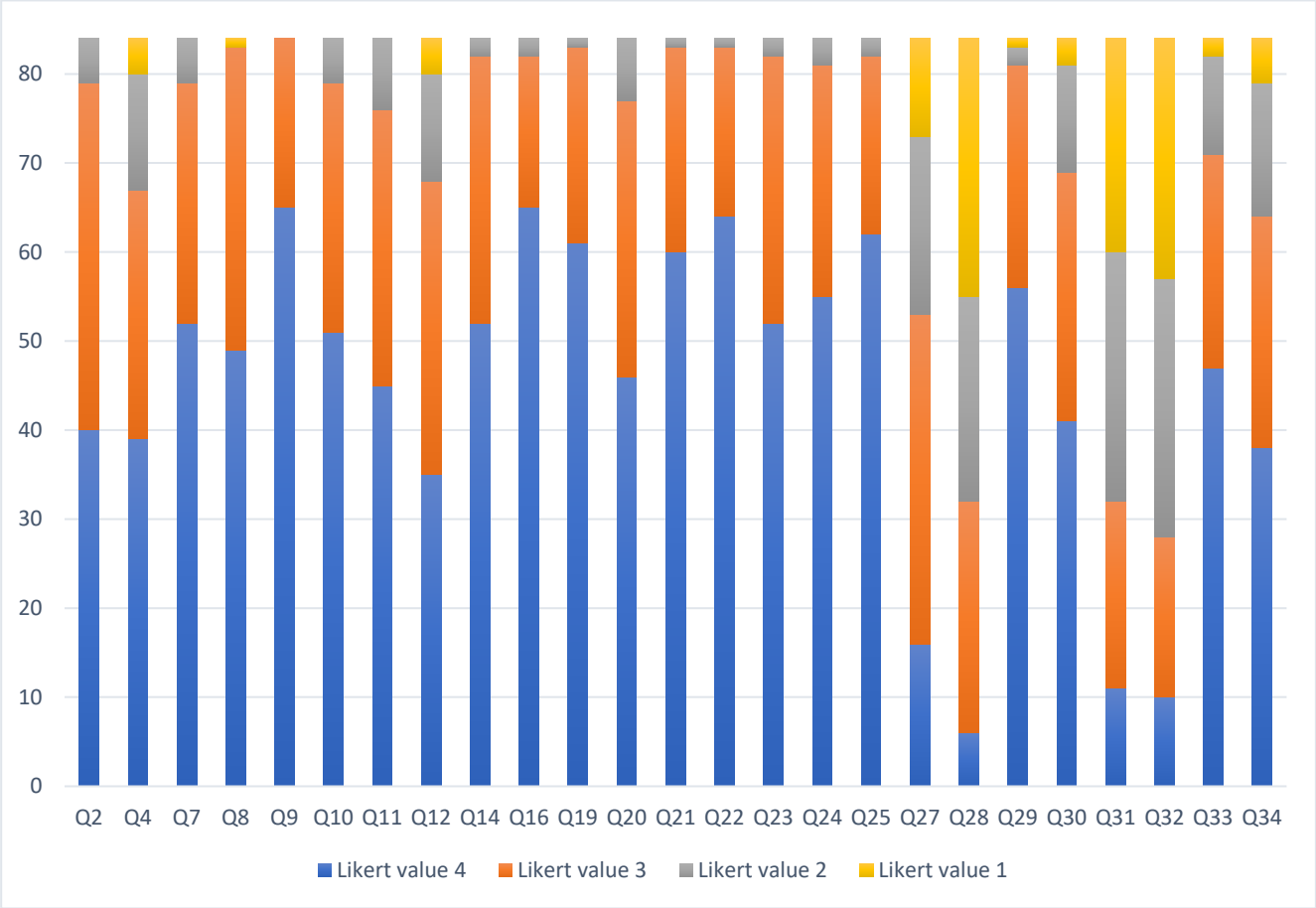

Figure 4. Results of students' responses.

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?

References

1. Ariza, C.P.; Rueda Toncel, L.Á. La educación ambiental: Una mirada desde el contexto universitario. *Bol. Redipe* **2016**, *5*, 116–124.
2. Apodaca Orozco, G.U.G.; Ortega Pipper, L.P.; Verdugo Blanco, L.E.; Reyes Barribas, L.E. Modelos educativos: Un reto para la educación en salud. *Ra Ximhai* **2017**, *13*, 77–86. [CrossRef]
3. Avendaño, C.W. Un modelo pedagggico para la educación ambienta desde la perspectiva de la moddificabilidad estructural cognitiva: A pedagogical model for enviromental education from the perspective of the cognitive structural modifiability. *Rev. Luna Azul* **2013**, *36*, 110–133.
4. Freidenfelds, D.; Kalnins, S.N.; Gusca, J. What does environmentally sustainable higher education institution mean? *Energy Procedia* **2018**, *147*, 42–47. [CrossRef]
5. Pita-Morales, L.A. Línea de tiempo: Educación ambiental en Colombia. *Praxis* **2016**, *12*, 118–125. [CrossRef]
6. Castillo, R.M. La importancia de la educación ambiental ante la problemática actual. *Rev. Electron. Educ.* **2010**, *14*, 97–111. [CrossRef]
7. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution Adopted by the General Assembly on 25 September 2015*; United Nations: New York, NY, USA, 2015.
8. Sánchez-Carracedo, F.; Sureda, B.; Moreno-Pino, F.M.; Romero-Portillo, D. Education for Sustainable Development in Spanish Engineering Degrees. Case study. *J. Clean. Prod.* **2021**, *294*, 126322. [CrossRef]

9. Vargas, V.R.; Lawthom, R.; Prowse, A.; Randles, S.; Tzoulas, K. Implications of vertical policy integration for sustainable development implementation in higher education institutions. *J. Clean. Prod.* **2019**, *235*, 733–740. [CrossRef]
10. Nousheen, A.; Yousuf Zai, S.A.; Waseem, M.; Khan, S.A. Education for sustainable development (ESD): Effects of sustainability education on pre-service teachers' attitude towards sustainable development (SD). *J. Clean. Prod.* **2020**, *250*, 119537. [CrossRef]
11. UNESCO. *Education for Sustainable Development Goals: Learning Objectives. Education for Sustainable Development. The Global Education 2030 Agenda*; UNESCO: Paris, France, 2017; ISBN 978-92-3-100209-0.
12. Lozano, R.; Ceulemans, K.; Alonso-Almeida, M.; Huisingh, D.; Lozano, F.J.; Waas, T.; Lambrechts, W.; Lukman, R.; Hugé, J. A review of commitment and implementation of sustainable development in higher education: Results from a worldwide survey. *J. Clean. Prod.* **2015**, *108*, 1–18. [CrossRef]
13. Lozano, R.; Lukman, R.; Lozano, F.J.; Huisingh, D.; Lambrechts, W. Declarations for sustainability in higher education: Becoming better leaders, through addressing the university system. *J. Clean. Prod.* **2013**, *48*, 10–19. [CrossRef]
14. Radinger-Peer, V.; Pflitsch, G. The role of higher education institutions in regional transition paths towards sustainability: The case of Linz (Austria). *Rev. Reg. Res.* **2017**, *37*, 161–187. [CrossRef]
15. Mbah, M. Can local knowledge make the difference? Rethinking universities' community engagement and prospect for sustainable community development. *J. Environ. Educ.* **2019**, *50*, 11–22. [CrossRef]
16. Holst, J.; Brock, A.; Singer-Brodowski, M.; de Haan, G. Monitoring Progress of Change: Implementation of Education for Sustainable Development (ESD) within Documents of the German Education System. *Sustainability* **2020**, *12*, 4306. [CrossRef]
17. Blattman, C.; Jamison, J.; Koroknay-Palicz, T.; Rodrigues, K.; Sheridan, M. Measuring the measurement error: A method to qualitatively validate survey data. *J. Dev. Econ.* **2016**, *120*, 99–112. [CrossRef]
18. Valdelamar-Villegas, J.; Olivero-Verbel, J. High Mercury Levels in the Indigenous Population of the Yaigojé Apaporis National Natural Park, Colombian Amazon. *Biol. Trace Elem. Res.* **2020**, *194*, 3–12. [CrossRef]
19. Olsson, D.; Gericke, N. The effect of gender on students' sustainability consciousness: A nationwide Swedish study. *J. Environ. Educ.* **2017**, *48*, 357–370. [CrossRef]
20. Mulà, I.; Tilbury, D.; Ryan, A.; Mader, M.; Dlouhá, J.; Mader, C.; Benayas, J.; Dlouhý, J.; Alba, D. Catalysing Change in Higher Education for Sustainable Development: A review of professional development initiatives for university educators. *Int. J. Sustain. High. Educ.* **2017**, *18*, 798–820. [CrossRef]
21. Herremans, I.M.; Reid, R.E. Developing awareness of the sustainability concept. *J. Environ. Educ.* **2002**, *34*, 16–20. [CrossRef]
22. Dlouhá, J.; Pospíšilová, M. Education for Sustainable Development Goals in public debate: The importance of participatory research in reflecting and supporting the consultation process in developing a vision for Czech education. *J. Clean. Prod.* **2018**, *172*, 4314–4327. [CrossRef]
23. Venkataraman, B. Education for sustainable development. *Environment* **2009**, *51*, 8–10. [CrossRef]
24. Kopnina, H. Education for sustainable development (ESD): Exploring anthropocentric-ecocentric values in children through vignettes. *Stud. Educ. Eval.* **2014**, *41*, 124–132. [CrossRef]
25. Ardoin, N.M.; Bowers, A.W. Early childhood environmental education: A systematic review of the research literature. *Educ. Res. Rev.* **2020**, *31*, 100353. [CrossRef] [PubMed]
26. Arellano, J.; Jaime, D.; Pantoja, E.G. *Ingeniería Ambiental*, 1st ed.; Alfaomega, Ed.; Alfaomega: Mexico City, Mexico, 2011; ISBN 9786077072331.
27. Touhill, C.J.; Clesceri, N.L.; Clark, H.M. What was the First University to Grant Environmental Engineering Degrees? In Proceedings of the World Water Congress 2005: Impacts of Global Climate Change—Proceedings of the 2005 World Water and Environmental Resources Congress, Anchorage, AK, USA, 15–19 May 2005; pp. 1–11. [CrossRef]
28. García Durán, G. Surgimiento y evolución de la Ingeniería Ambiental en Colombia. *Rev. Ing.* **2007**, *26*, 122–130. [CrossRef]
29. Tilbury, D. Environmental Education for Sustainability: Defining the new focus of environmental education in the 1990s. *Environ. Educ. Res.* **1995**, *1*, 195–212. [CrossRef]
30. Kolmos, A.; Hadgraft, R.G.; Holgaard, J.E. Response strategies for curriculum change in engineering. *Int. J. Technol. Des. Educ.* **2016**, *26*, 391–411. [CrossRef]
31. Zowada, C.; Belova, N.; Eilks, I. Enhancing Education for Sustainable Development Through Geographical Perspectives in Chemistry Teaching. *Int. J. Sci. Math. Educ.* **2021**, *19*, 87–109. [CrossRef]
32. Sas-Bojarska, A. EIA in teaching sustainable development and environmental protection in engineering education. *World Trans. Eng. Technol. Educ.* **2020**, *18*, 139–145.
33. Ramos Torres, D.I. Contribution of higher education to the Sustainable Development Goals from teaching. *Rev. Esp. Educ. Comp.* **2021**, *37*, 89–110. [CrossRef]
34. Geng, Y.; Zhao, N. Measurement of sustainable higher education development: Evidence from China. *PLoS ONE* **2020**, *15*, e0233747. [CrossRef]
35. Chaves, M.; Macintyre, T.; Verschoor, G.; Wals, A.E.J. Towards transgressive learning through ontological politics: Answering the "call of the mountain" in a Colombian network of sustainability. *Sustainability* **2017**, *9*, 21. [CrossRef]
36. Quiva, D.; Vera, L. La educación ambiental como herramienta para promover el desarrollo sostenible. *Telos* **2010**, *12*, 378–394.
37. Molano, A.; Herrera, J. La formación ambiental en la educación superior:una revisión necesaria. *Luna Azul* **2014**, *2*, 186–206. [CrossRef]

38. Van Poeck, K.; Goeminne, G.; Vandenabeele, J. Revisiting the democratic paradox of environmental and sustainability education: Sustainability issues as matters of concern. *Environ. Educ. Res.* **2016**, *22*, 806–826. [CrossRef]
39. Sund, L.; Öhman, J. On the need to repoliticise environmental and sustainability education: Rethinking the postpolitical consensus. *Environ. Educ. Res.* **2014**, *20*, 639–659. [CrossRef]
40. Rendón López, L.M.; Londoño, J.V.E.; de Jesús Arango Ruiz, Á.; Benítez, J.A.M.; Parodi, T.V.; Montaña, D.F.V. Education for sustainable development: Approaches froma Colombian perspective. *Prod. Y Limpia* **2018**, *13*, 133–149. [CrossRef]
41. Mora Penagos, W.M. Educación ambiental y educación para el desarrollo sostenible ante la crisis planetaria: Demandas a los procesos formativos del profesorado. *TED Tecné Epistem. Didaxis* **2009**, 7–35. [CrossRef]
42. Carrasco, M.E.; Vásquez, E. La Educación Ambiental un saber necesario en la formación universitaria. *Rev. Interam. Educ. Adultos* **2016**, *38*, 77–93.
43. UNESCO Libro de Consulta sobre la Educación para el Desarrollo Sostenible. *Instrum. Aprendiz. Y Form.* **2012**, *4*, 53.
44. Mejía-Cáceres, M.A.; Huérfano, A.; Reid, A.; Freire, L.M. Colombia's national policy of environmental education: A critical discourse analysis. *Environ. Educ. Res.* **2020**, *27*, 571–594. [CrossRef]
45. Berdugo Silva, N.C.; Montaño Renuma, W.Y. La educación ambiental en las instituciones de educación superior públicas acreditadas en Colombia. *Rev. Cient. Gen. José María Córdova* **2017**, *15*, 127. [CrossRef]
46. Mitsch, W. What is ecological engineering? *Ecol. Eng.* **2012**, *45*, 5–12. [CrossRef]
47. ONU La Asamblea General adopta la Agenda 2030 para el Desarrollo Sostenible. *Cent. Inf. Das Nações Unidas Para O Bras.* **2015**, *14*, 72.
48. Matarrita Baccá, R.; Tuk Mena, E. El papel estratégico de a educación para el desarrollo sostenible. *Rev. Educ.* **2011**, *25*, 19. [CrossRef]
49. Rengifo Rengifo, B.A.; Quitiaquez Segura, L.; Mora Córdoba, F.J. La educación ambiental una estrategia pedagógica que contribuye a la solución de la problemática ambiental en Colombia. In Proceedings of the XII Coloquio Internacional de Geocrítica, Pasto, Colombia, 7–11 May 2012; pp. 1–16.
50. Gutiérrez, J.; Benayas, J.; Calvo, S. Educación para el Desarrollo Sostenible: Evaluación de retos y oportunidades del decenio 2005–2014. *Rev. Iberoam. Educ.* **2006**, *40*, 25–69. [CrossRef]
51. Kyburz-Graber, R. Case Study Research on Higher Education for Sustainable Development. In *Routledge Handbook of Higher Education for Sustainable Development*; Barth, M., Rieckmann, M., Thomas, I., Eds.; Routledge: London, UK, 2015; pp. 150–165, ISBN 9781315852249.
52. UNESCO. *Educación Para el Desarrollo Sostenible Educación Para el Desarrollo Sostenible Aportes didácticos*; Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura: Paris, France, 2012; ISBN 978-92-3-001077-5.
53. EOI. La Educación para el Desarrollo Sostenible. Available online: https://www.eoi.es/blogs/msoston/2016/03/29/la-educacion-para-el-desarrollo-sostenible-eds/ (accessed on 6 July 2022).
54. Elmassah, S.; Biltagy, M.; Gamal, D. Framing the role of higher education in sustainable development: A case study analysis. *Int. J. Sustain. High. Educ.* **2021**, *23*, 320–355. [CrossRef]
55. Desha, C.J.; Hargroves, K.C.; Smith, M.H. Addressing the time lag dilemma in curriculum renewal towards engineering education for sustainable development. *Int. J. Sustain. High. Educ.* **2009**, *10*, 184–199. [CrossRef]
56. Acosta Castellanos, P.M.; Queiruga-Dios, A.; Álvarez, L.G. Inclusion of Education for Sustainable Development in Environmental Engineering. A Systematic Review. *Sustainability* **2021**, *13*, 10180. [CrossRef]
57. Jones, P.; Trier, C.J.; Richards, J.P. Embedding Education for Sustainable Development in higher education: A case study examining common challenges and opportunities for undergraduate programmes. *Int. J. Educ. Res.* **2008**, *47*, 341–350. [CrossRef]
58. Lozano, R.; Lozano, F.J.; Mulder, K.; Huisingh, D.; Waas, T. Advancing Higher Education for Sustainable Development: International insights and critical reflections. *J. Clean. Prod.* **2013**, *48*, 3–9. [CrossRef]
59. Yuan, X.; Zuo, J. A critical assessment of the Higher Education For Sustainable Development from students' perspectives—A Chinese study. *J. Clean. Prod.* **2013**, *48*, 108–115. [CrossRef]
60. Barth, M.; Rieckmann, M. Academic staff development as a catalyst for curriculum change towards education for sustainable development: An output perspective. *J. Clean. Prod.* **2012**, *26*, 28–36. [CrossRef]
61. Saris, W.E.; Gallhofer, I.N. *Design, Evaluation, and Analysis of Questionnaires for Survey Research*, 2nd ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2007; ISBN 9780470165195.
62. Weijters, B.; Millet, K.; Cabooter, E. Extremity in horizontal and vertical Likert scale format responses. Some evidence on how visual distance between response categories influences extreme responding. *Int. J. Res. Mark.* **2020**, *38*, 85–103. [CrossRef]
63. Höhne, J.K.; Krebs, D.; Kühnel, S.-M. Measurement properties of completely and end labeled unipolar and bipolar scales in Likert-type questions on income (in)equality. *Soc. Sci. Res.* **2021**, *97*, 102544. [CrossRef]
64. Karatzoglou, B. An in-depth literature review of the evolving roles and contributions of universities to Education for Sustainable Development. *J. Clean. Prod.* **2013**, *49*, 44–53. [CrossRef]
65. Cepeda, S.S. Diagnóstico y Perspectiva de la Educación Ambiental en Extremadura, Universidad de Extremadura. 2002. Available online: https://redined.educacion.gob.es/xmlui/handle/11162/133420?show=full (accessed on 6 July 2022).
66. Cortina, J.M. What Is Coefficient Alpha? An Examination of Theory and Applications. *J. Appl. Psychol.* **1993**, *78*, 98–104. [CrossRef]
67. de Vet, H.C.W.; Mokkink, L.B.; Mosmuller, D.G.; Terwee, C.B. Spearman–Brown prophecy formula and Cronbach's alpha: Different faces of reliability and opportunities for new applications. *J. Clin. Epidemiol.* **2017**, *85*, 45–49. [CrossRef]

68. Warrens, M.J. Some Relationships Between Cronbach's Alpha and the Spearman-Brown Formula. *J. Classif.* **2015**, *32*, 127–137. [CrossRef]
69. Vonglao, P. Application of fuzzy logic to improve the Likert scale to measure latent variables. *Kasetsart J. Soc. Sci.* **2017**, *38*, 337–344. [CrossRef]
70. Zheng, X.; Wang, R.; Hoekstra, A.Y.; Krol, M.S.; Zhang, Y.; Guo, K.; Sanwal, M.; Sun, Z.; Zhu, J.; Zhang, J.; et al. Consideration of culture is vital if we are to achieve the Sustainable Development Goals. *One Earth* **2021**, *4*, 307–319. [CrossRef]
71. Harpe, S.E. How to analyze Likert and other rating scale data. *Curr. Pharm. Teach. Learn.* **2015**, *7*, 836–850. [CrossRef]
72. Furley, T.H.; Brodeur, J.; de Assis, H.C.S.; Carriquiriborde, P.; Chagas, K.R.; Corrales, J.; Denadai, M.; Fuchs, J.; Mascarenhas, R.; Miglioranza, K.S.; et al. Toward sustainable environmental quality: Identifying priority research questions for Latin America. *Integr. Environ. Assess. Manag.* **2018**, *14*, 344–357. [CrossRef] [PubMed]
73. CODS. *Índice ODS 2019 Para América Latina y el Caribe*; Bogotá: Colombia, UK, 2019.
74. Stössel, J.; Baumann, R.; Wegner, E. Predictors of Student Teachers' ESD Implementation Intention and Their Implications for Improving Teacher Education. *Sustainability* **2021**, *13*, 9027. [CrossRef]
75. Parrado, A.; Trujillo, H. Universidad y sostenibilidad: Una aproximación teórica para su implementación. *AD Minist.* **2015**, *26*, 149–163. [CrossRef]
76. Keeble, B.R. The Brundtland Report: "Our Common Future. *Med. War* **1988**, *4*, 17–25. [CrossRef]
77. Ministerio de Educación Nacional Decreto 1743 de 1994. Diario Oficial No. 41476. a 3 de agosto de 1994. 1994; Volume 1994, p. 7. Available online: https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=1301#:~{}:text=por%20el%20cual%20se%20instituye,el%20Ministerio%20del%20Medio%20Ambiente (accessed on 4 May 2021).
78. Flórez-Yepes, G.Y. La educación ambiental y el desarrollo sostenible en el contexto colombiano. *Rev. Electron. Educ.* **2015**, *19*, 1–12. [CrossRef]
79. Pleasants, J.; Tank, K.M.; Olson, J.K. Conceptual connections between science and engineering in elementary teachers' unit plans. *Int. J. STEM Educ.* **2021**, *8*, 1–17. [CrossRef]
80. Berglund, T.; Gericke, N.; Chang Rundgren, S.N. The implementation of education for sustainable development in Sweden: Investigating the sustainability consciousness among upper secondary students. *Res. Sci. Technol. Educ.* **2014**, *32*, 318–339. [CrossRef]
81. Sepúlveda Chaverra, J.D. Estado de la Investigación Sobre Educación Para El Desarrollo Sostenible: Un Análisis Cienciométrico de la Producción Científica En El Periodo 2005–2014. *Luna Azul* **2015**, *41*, 309–322. [CrossRef]
82. Arango, S. *Educar Para la Sostenibilidad en la Universidad: Una Propuesta Didáctica Para el Fortalecimiento de Competencias*; Universidad de Ciencias Aplicadas y Ambientales: Bogotá, Colombia, 2020.
83. Hernandez-Diaz, P.M.; Polanco, J.A.; Castaño, S.M. Do sustainability practices influence university quality? A Colombian case study. *Int. J. Sustain. High. Educ.* **2020**, *21*, 1525–1543. [CrossRef]
84. Callejas Restrepo, M.M.; Blanco-Portela, N.; Ladino-Ospina, Y.; Tuay Sigua, R.N.; Vargas, K.O. Professional development of university educators in ESD: A study from pedagogical styles. *Int. J. Sustain. High. Educ.* **2017**, *18*, 648–665. [CrossRef]
85. Alvarez-Risco, A.; Del-Aguila-Arcentales, S.; Rosen, M.A.; García-Ibarra, V.; Maycotte-Felkel, S.; Martínez-Toro, G.M. Expectations and interests of university students in COVID-19 times about sustainable development goals: Evidence from colombia, ecuador, mexico, and peru. *Sustainability* **2021**, *13*, 3306. [CrossRef]
86. Lozano, F.J.; Lozano, R. Developing the curriculum for a new Bachelor's degree in Engineering for Sustainable Development. *J. Clean. Prod.* **2014**, *64*, 136–146. [CrossRef]
87. Velazquez, L.; Munguia, N.; Sanchez, M. Deterring sustainability in higher education institutions: An appraisal of the factors which influence sustainability in higher education institutions. *Int. J. Sustain. High. Educ.* **2005**, *6*, 383–391. [CrossRef]
88. Lozano, R. Incorporation and institutionalization of SD into universities: Breaking through barriers to change. *J. Clean. Prod.* **2006**, *14*, 787–796. [CrossRef]
89. Peet, D.J.; Mulder, K.F.; Bijma, A. Integrating SD into engineering courses at the Delft University of Technology: The individual interaction method. *Int. J. Sustain. High. Educ.* **2004**, *5*, 278–288. [CrossRef]
90. Ssossé, Q.; Wagner, J.; Hopper, C. Assessing the impact of ESD: Methods, challenges, results. *Sustainability* **2021**, *13*, 2854. [CrossRef]
91. Barab, S.A.; Luehmann, A.L. Building Sustainable Science Curriculum: Acknowledging and Accommodating Local Adaptation. *Sci. Educ.* **2003**, *87*, 454–467. [CrossRef]
92. Murray, P.; Goodhew, J.; Murray, S. The heart of ESD: Personally engaging learners with sustainability. *Environ. Educ. Res.* **2014**, *20*, 718–734. [CrossRef]
93. Žalėnienė, I.; Pereira, P. Higher Education For Sustainability: A Global Perspective. *Geogr. Sustain.* **2021**, *2*, 99–106. [CrossRef]
94. Kitamura, Y. The possibility of holistic safety education in Japan: From the perspective of Education for Sustainable Development (ESD). *IATSS Res.* **2014**, *38*, 40–47. [CrossRef]
95. Trad, S.P. A framework for mapping sustainability within tertiary curriculum. *Int. J. Sustain. High. Educ.* **2019**, *20*, 288–308. [CrossRef]
96. Chavarro, D.; Vélez, I.; Tovar, G.; Montenegro, I.; Hernández, A.; Olaya, A. Los Objetivos de Desarrollo Sostenible en Colombia y el Aporte de la Ciencia, la Tecnología y la Innovación. 2017. Available online: https://minciencias.gov.co/sites/default/files/objetivos_de_desarrollo_sostenible_y_aporte_a_la_cti_v_3.5.pdf (accessed on 6 July 2022).

7. PUBLICACIONES COMPLEMENTARIAS

Además de las publicaciones necesarias y exigidas por la Universidad de Salamanca para la presentación de la tesis doctoral por compendio de artículos, se realizaron otras publicaciones a partir de los datos que se recogieron durante esta investigación. Como criterio para estas publicaciones se consideró la calidad de los eventos y la idexación dentro de las bases de datos de publicaciones científicas. Así mismo, se publicó un artículo adicional sobre una revisión sistemática de literatura que fue la base para el primer artículo presentado en esta tesis.

A continuación se presenta el listado de las referencas bibliograficas de los trabajos complementarios:

7.1. Título: Inclusion of Education for Sustainable Development in Environmental Engineering. A Systematic Review.

- Autores: Acosta Castellanos, P. M., Queiruga Dios, A., Gómez Araque, L., & Rojas Ramos.
- Nombre de revista: Sustainability
- Volumen: 13
- Páginas: 1-11
- Año de publicación: 2021
- DOI: 10.3390/su131810180
- Editorial: MDPI

- ISSN: 2071-1050
- Proceso de publicación:
    - ✓ Enviado: 25 de junio de 2021
    - ✓ Revisado: 5 de agosto de 2021
    - ✓ Disponible online: 12 de septiembre de 2021
- Revista indexada en Web of Science (2021):
    - ✓ Factor de impacto: 3.889
    - ✓ Factor de impacto a 5 años: 4.089
    - ✓ Ranking de la revista: Environmental Studies, 57/127, Q2
- Revista indexada en Scopus: (2021)
    - ✓ Impacto de citación: 0.664
- Ranking de la revista: Environmental Science (miscellaneous), 20/133, Q1

7.2. Título: The Evolution from the Environmental Education Model to the Education for Sustainable Development Model. Case Study of Environmental Engineering at Santo Tomas University, Colombia.

- Autores: Acosta Castellanos, P. M., Queiruga-Dios, A., & Álvarez, L. González.
- Conferencia: TEEM 2020
- Publicación: ACM International Conference Proceeding Series
- Páginas: 105-113
- Año de publicación: 2020

- DOI: 10.3390/su131810180
- Editorial: ACM
- ISSN: 978-145038850-4
- Indexado en Scopus, ACM.

7.3. Título: Analysis of environmental sustainability educational approaches in engineering education.

- Autores: Acosta Castellanos, P. M., Encinas, A. H., Queiruga-Dios, A., & Ortegón, A. C.
- Conferencia: CISTI, 2020
- Publicación: IEEE
- Páginas: 1-5
- Año de publicación: 2020
- DOI: 10.23919/CISTI49556.2020.9140919
- Editorial: IEEE Xplore
- ISSN: 2166-0727
- Indexado en Scopus, IEEE

7.4. Título: The lack of environmental education in the training of environmental engineers in Colombia.

- Autores: Acosta Castellanos, P. M., Queiruga-Dios, A., & Ortegón, A. C.
- Conferencia: SEFI 47 th Annual Conference

- Páginas: 1-5
- Año de publicación: 2020
- Editorial: SEFI
- ISSN: 978-287352018-2
- Indexado en Scopus.

7.5. Título: Current state of knowledge of ESD in environmental engineering professors in Colombia.

- Autores: Acosta Castellanos, P. M., & Queiruga-Dios, A.
- Conferencia: SEFI 49th Annual Conference
- Páginas: 72-86
- Año de publicación: 2021
- Editorial: SEFI
- ISSN: 978-287352023-6
- Indexado en Scopus.

8. CONCLUSIONES

La educación de desarrollo sostenible es una tendencia que ha ganado fuerza dentro de las instituciones de educación superior a nivel mundial. A pesar de ello, es dificil encontrar procesos de aplicación masiva o integral de la EDS en los planes de estudio de las universidades, aunque la finalidad de la UNESCO era lograr que la EDS estuviera en cada nivel de educativo y que fuera visible dentro de los currículos. Sin embargo, este objetivo resulta dificil de lograr, puesto que la EDS encuentra dificultades en su misma concepción y fundamentación. La EDS es antropocéntrica y tiene su fundamento en la teoría del DS, lo que genera una contraposición frente a quienes están en contra del desarrollo y del propio antropocentrismo, más aún en la ultimad década, cuando se formuló el denominado "antropoceno", que evidencia todos los perjuicios ambientales que ha conllevado el apoyar acciones con propósitos centrados únicamente en el bienestar humano. Este hecho se evidenció con las encuestas que se aplicaron como parte de las investigaciones de esta tesis, tanto a estudiantes y profesores de diferentes áreas de conocimiento. Así mismo, mediante las revisiones sistemáticas de la literatura, se demostró la poca aplicabilidad que tiene la EDS dentro de las universidades, se encontraron menos de diez ejemplos curriculares donde se integraba la EDS dentro de programas de grado.

Por otro lado, gracias a las encuestas realizadas a docentes y estudiantes de ingenierías de diferentes universidades en Colombia y Latinoamerica, se evidenció que existe un desconocimiento de la EDS como corriente alternativa a la EA. Esto se debe a que la EA

tiene un recorrido mayor y sigue siendo el modelo aplicado dentro de las instituciones educativas, desde educación primaria hasta los estudios universitarios. En Colombia, el apoyo gubernamental y no gubernamental a la EA resulta evidente, los consejos departamentales de educación ambiental y el consejo nacional de educación ambiental reunen empresas, organizaciones, universidades, colegios y todo tipo de actores económicos, sociales y educativos para impulsar la EA. Además, existe una política de educación ambiental que data del año 2002, en su última actualización, y que, hasta el momento, no muestra rasgos de cambio hacia la EDS. La EA resulta atractiva para Latinoamerica, puesto que es un medio de canalización de las frustaciones que generó en la población la extracción desmedida e irresponsable de los recursos naturales a finales del siglo XX por parte de multinacionales. La EA se convirtió en una fuente académica fiable para soportar las protestas, manifesticiones y todo tipo de expresiones sociales frente a la destrucción del medio ambiente por parte de grandes empresas. Esto se debió a la naturaleza misma de la EA, que antepone el bien natural o ambiental por encima del bien humano. Por su parte, la EDS irrumpió en este pensamiento, ya arraigado socialmente, y resulta dificil de imponer o ni siquiera de sugerir, lo cual se logró demostrar mediante la encuesta realizada como parte de esta investigación, a profesores de ingeniería ambiental del país. Una de las conclusiones que se constataron fue que los docentes no están abiertos a una EDS atropocentrista, sino que se inclinan por una corriente que logre mediar y equilibrar la proteccion ambiental y las necesidades humanas. Por otro lado, los estudiantes se muestran más abiertos a aprender sobre la EDS que los profesores y tienen una mayor familiaridad con términos relacionados

con el DS, aunque con carencias y confusiones, que se producen por la falta de preparación formal. Los estudiantes han utilizado, como mayor fuente de capacitación e información en DS, los espacios extracurriculares, tales como congresos, cursos y seminarios, pero resulta casi nula la información o capacitación que tienen de fuentes curriculares dentro de sus estudios de grado.

La integración de una asignatura de EDS dentro del currículo de ingeniería ambiental, en la Universidad Santo Tomás de Colombia, fue una oportunidad única para experimentar curricularmente y poder medir los diferentes factores que pueden estar involucrados en un cambio curricular. La inclusión de una asignatura es, habitualmente, la manara más efectiva que se puede encontrar para vincular formalmente un tema con la formación de una profesión, dentro de un programa de grado o postgrado. Si bien existen otras formas menos intrusivas, estas son más dificiles de medir, y su efectividad varía debido a la interdependencia de muchos factores. Con la adición de la EDS como asignatura, dentro del plan de estudios de ingeniería ambiental, se logró llenar dos grandes vacíos que se identifacaron en las primeras etapas de esta investigación: la falta de preparación en EDS por parte de los docentes y la falta de formación en EDS por parte de los estudiantes. Ambos vacíos están interconectados y son dependientes, pues el docente debe estar preparado para impartir la asignatura, lo que le empuja a su cualificación y a la adquisión de habilidades y competencias relacionadas con la EDS. También los estudiantes se benefician al recibir la información precisa sobre la EDS por parte del profesor.

Aún integrando la materia de EDS en el plan de estudios, los estudiantes siguen teniendo un cierto grado de afinidad con el proteccionismo propio de la instrucción que brinda la EA, pero, en cambio, los estudiantes que participaron en la asignatura de EDS han resultado estar más alfabetizados en las formas de participar y mediar entre las necesidades económicas y sociales y el medio ambiente.

Finalmente, es importante mencionar que cada etapa de esta investigación puede ser tomada como un modelo de evaluación y actualización curricular para incluir, mediante la metodología utilizada, temas novedosos y actuales, que deben ser ensayados y probados por la comunidad académica de cualquier programa de grado o postgrado. La EDS aún tiene un largo camino por recorrer en Latinoamérica y en otros muchos países, especialmente en la educación superior. La inclusión de una asignatura sobre EDS puede considerarse adecuada, tal como ocurrió en su momento con la asignatura de ética, presente en todos los currículos de ingeniería. Pues al igual que ocurre con la ética en las profesiones, es necesario capacitar a los futuros profesionales en el área ambiental y que esta formación sea transversal a su pensamiento y quehacer cotidiano para que, desde sus acciones, se genere el cambio que el planeta, y especialmente la humanidad, necesitan en términos ambientales.

9. REFERENCIAS

Acosta Castellanos, P. M., Queiruga-Dios, A., Encinas, A. H., & Acosta, L. C. (2020). Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America. *Sustainability*, *12*(18), 7239. https://doi.org/10.3390/su12187239

Acosta Castellanos, P. M., Queiruga-Dios, A., & Ortegón, A. C. (2020b). The lack of environmental education in the training of environmental engineers in Colombia. In SEFI (Ed.), *SEFI 47th Annual Conference: Varietas Delectat... Complexity is the New Normality, Proceedings* (pp. 70–82). European Society for Engineering Education (SEFI).

Acosta Castellanos, P. M., & Queiruga-Dios, A. (2022). From environmental education to education for sustainable development in higher education: a systematic review. *International Journal of Sustainability in Higher Education*, *23*(3), 622–644. https://doi.org/10.1108/IJSHE-04-2021-0167

Acosta-Castellanos, P. M., & Queiruga-Dios, A. (2022b). Education for Sustainable Development (ESD): An Example of Curricular Inclusion in Environmental Engineering in Colombia. *Sustainability*, *14*(16), 9866. https://doi.org/10.3390/su14169866

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, *241*, 108224. https://doi.org/10.1016/j.biocon.2019.108224

Asch, J., & Shore, B. M. (1975). Conservation behavior as the outcome of environmental education. *Journal of Environmental Education*, *6*(4), 25–33. https://doi.org/10.1080/00958964.1975.9942002

Balza-Franco, V. (2016). Formulación y diseño de un modelo de vigilancia tecnológica curricular en programas de ingeniería en Colombia. *Revista de La Educacion Superior*, *45*(179), 55–77. https://doi.org/10.1016/j.resu.2016.04.008

Barriga, F. D. (1993). Aproximaciones metodológicas al diseño curricular: hacia una propuesta integral. *Tecnología y Comunicación Educativas*, *21*(21), 19–39.

Barry, C. (2006). Environmental Education is History: The Extent to Which Modern History Education Adopts Characteristics of Socially Critical Environmental Education. *Australian Journal of Environmental Education*, *22*(1), 3–13. http://www.jstor.org/stable/44656606

Becker, G. (2018). Climate Change Education for Sustainable Development in Urban Educational Landscapes and Learning Cities. Experiences Perspectives from Osnabrück. In U. M. Azeiteiro, M. AKERMAN, W. Leal Filho, A. F. F. Setti, & L. L. Brandli (Eds.), *World Sustainability Series* (pp. 439–469). Springer International Publishing. https://doi.org/10.1007/978-3-319-69474-0_26

Carter, R. L., & Simmons, B. (2010). The History and Philosophy of Environmental Education. In A. M. Bodzin, B. Shiner Klein, & S. Weaver (Eds.), *The Inclusion of Environmental Education in Science Teacher Education* (pp. 3–16). Springer Netherlands.

https://doi.org/10.1007/978-90-481-9222-9_1

British Educational Research Association (BERA). (2018). *Ethical guidelines for educational research*. British Educational Research Association.

Biasi, P., Ferrini, S., Borghesi, S., Rocchi, B., & Di Matteo, M. (2019). Enriching the Italian Genuine Saving with water and soil depletion: National trends and regional differences. *Ecological Indicators*, *107*(105573), 105573. https://doi.org/10.1016/j.ecolind.2019.105573

Bush, D., Sieber, R., Seiler, G., & Chandler, M. (2017). University-level teaching of Anthropogenic Global Climate Change (AGCC) via student inquiry. *Studies in Science Education*, *53*(2), 113–136. https://doi.org/10.1080/03057267.2017.1319632

Carrasco, M. E., & Vásquez, E. (2016). La Educación Ambiental un saber necesario en la formación universitaria. *Revista Interamericana de Educación de Adultos*, *38*(2), 77–93. https://www.redalyc.org/pdf/4575/457546143005.pdf

de Andrade Guerra, J. B. S. O., Garcia, J., de Andrade Lima, M., Barbosa, S. B., Heerdt, M. L., & Berchin, I. I. (2018). A proposal of a Balanced Scorecard for an environmental education program at universities. *Journal of Cleaner Production*, *172*, 1674–1690. https://doi.org/10.1016/j.jclepro.2016.11.179

García Durán, G. (2007). Surgimiento y evolución de la Ingeniería Ambiental en Colombia. *Revista de Ingeniería*, *26*, 121–130. https://doi.org/10.16924/revinge.26.13

Gille, W. (1996). Environmental education. *European Education*, *28*(3), 71–81. https://doi.org/10.2753/EUE1056-4934280371

González-Gaudiano, E. J. (2016). ESD: Power, politics, and policy: "Tragic optimism" from Latin America. *Journal of Environmental Education*, *47*(2), 118–127. https://doi.org/10.1080/00958964.2015.1072704

Hernández-Díaz, P. M., Polanco, J. A., & Castaño, S. M. (2020). Do sustainability practices influence university quality? A Colombian case study. *International Journal of Sustainability in Higher Education*, *21*(7), 1525–1543. https://doi.org/10.1108/IJSHE-03-2020-0087.

Higgitt, D. (2006). Finding space for education for sustainable development in the enterprise economy. *Journal of Geography in Higher Education*, *30*(2), 251–262. https://doi.org/10.1080/03098260600717331

Klimska, A. (2021). Education for Sustainable Development from the Perspective of Mieczysław Gogacz's Realistic Pedagogy. *Seminare. Poszukiwania Naukowe*, *2021(42)*(4), 65–75. https://doi.org/10.21852/sem.2021.4.05

Kopnina, H. (2014). Education for sustainable development (ESD): Exploring anthropocentric-ecocentric values in children through vignettes. *Studies in Educational Evaluation*, *41*, 124–132. https://doi.org/10.1016/j.stueduc.2013.12.004

Last, J. M. (1987). Our common future. *Canadian Journal of Public Health = Revue Canadienne de Sante Publique*, *78*(6), 366–367. https://idl-bnc-idrc.dspacedirect.org/handle/10625/18365

Lozano, R. (2012). Incorporation and institutionalization of SD into universities: breaking through barriers to change. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2005.12.010

Lozano, R., Ceulemans, K., Alonso-Almeida, M., Huisingh, D., Lozano, F. J., Waas, T., Lambrechts, W., Lukman, R., & Hugé, J. (2015). A review of commitment and implementation of sustainable development in higher education: Results from a worldwide survey. *Journal of Cleaner Production*, *108*, 1–18. https://doi.org/10.1016/j.jclepro.2014.09.048

Maroto, J. P. (1969). La medicina y la ingeniería en la salud ambiental. *Revista de Obras Públicas*, 27.

Martínez, R. (2010). La importancia de la educación ante la problematica actual. *Revista Electrónica Educare*, *14*, 97–111.

Mbah, M. (2019). Can local knowledge make the difference? Rethinking universities' community engagement and prospect for sustainable community development. *Journal of Environmental Education*, *50*(1), 11–22. https://doi.org/10.1080/00958964.2018.1462136

McKeown, R., & Hopkins, C. (2003). EE p ESD: Defusing the worry. *Environmental*

Education Research, *9*(1), 117–128. https://doi.org/10.1080/13504620303469

Oviedo, H. C., & Campo-Arias, A. (2005). Aproximación al uso del coeficiente alfa de Cronbach. *Revista Colombiana de Psiquiatria*, *34*, 572–580. http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0034-74502005000400009&nrm=iso

Pita-Morales, L. A. (2016). Línea de tiempo: Educación Ambiental en Colombia. *Praxis*, *12*, 118–125. https://doi.org/10.21676/23897856.1853

Portocarrero-Sierra, L., Restrepo-Morales, J. A., & Arias-Calderón, J. E. (2020). Impact evaluation of high quality accreditation in Colombian higher education institutions. *Formacion Universitaria*, *13*(6), 37–50. https://doi.org/10.4067/S0718-50062020000600037

Radinger-Peer, V., & Pflitsch, G. (2017). The role of higher education institutions in regional transition paths towards sustainability: The case of Linz (Austria). *Review of Regional Research*, *37*(2), 161–187. https://doi.org/10.1007/s10037-017-0116-9

Ramos, T. B., Caeiro, S., Van Hoof, B., Lozano, R., Huisingh, D., & Ceulemans, K. (2015). Experiences from the implementation of sustainable development in higher education institutions: Environmental Management for Sustainable Universities. *Journal of Cleaner Production*, *106*, 3–10. https://doi.org/10.1016/j.jclepro.2015.05.110

Ramos Torres, D. I. (2021). Contribution of higher education to the Sustainable

Development Goals from teaching. *Revista Espanola de Educacion Comparada*, *37*(37), 89–110. https://doi.org/10.5944/REEC.37.2021.27763

Rendón López, L. M., Londoño, J. V. E., Ruiz, Á. D. J. A., Benítez, J. A. M., Parodi, T. V., & Montaña, D. F. V. (2018). Education for sustainable development: Approaches from a Colombian perspective. *Journal of cleaner production*, *13*(2), 133–149. https://doi.org/10.22507/pml.v13n2a7

Sánchez-Carracedo, F., & López, D. (2020). Innovation in Engineering Education for Sustainable Development—Introduction to a Special Issue. *Sustainability*, 12(19), 8132. https://doi.org/10.3390/su12198132

Schmidt, F. L., & Hunter, J. (2004). General Mental Ability in the World of Work: Occupational Attainment and Job Performance. *Journal of Personality and Social Psychology*, *86*(1), 162–173. https://doi.org/10.1037/0022-3514.86.1.162

Sosa, S., Márquez, I., Eastmond, A., Ayala, M., & Arteaga, M. (2010). Educación Superior y Cultura Ambiental en el Sureste de México. *Trópico Humedo*, *26*(1), 33–49. www.ujat.mx/publicaciones/uciencia

Stevenson, R. B., Brody, M., Dillon, J., & Wals, A. E. J. (2013). Conceptualizing Environmental Education as a Field of Inquiry. In R. B. Stevenson, M. Brody, J. Dillon, & A. E. J. Wals (Eds.), *International Handbook of Research on Environmental Education* (pp. 1–576). Routledge. https://doi.org/10.4324/9780203813331

UNESCO. (2012). Libro de Consulta sobre la Educación para el Desarrollo Sostenible. *Instrumentos de Aprendizaje y Formación*, *4*, 53. https://www.unesco.org/es/esd/videos/

Vail, D. D. (2010). DDT, Silent Spring, and the Rise of Environmentalism: Classic Texts. *Agricultural History*, *84*(1), 131–132. https://doi.org/10.1215/00021482-84.1.131

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., & Verbruggen, A. (2014). Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development. *Sustainability*, *6*(9), 5512–5534. https://doi.org/10.3390/su6095512

Warrens, M. J. (2015). Some Relationships Between Cronbach's Alpha and the Spearman-Brown Formula. *Journal of Classification*, *32*(1), 127–137. https://doi.org/10.1007/s00357-015-9168-0