



TESIS DOCTORAL

# Enfoques didácticos para la enseñanza de la Educación Ambiental: incorporando la ciencia ciudadana a la Didáctica de las Ciencias Experimentales

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“Mención Internacional”







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**Enfoques didácticos para la enseñanza de  
la Educación Ambiental: incorporando la  
ciencia ciudadana en la Didáctica de las  
Ciencias Experimentales**

Tesis Doctoral

Programa de Educación

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*"La constancia no está en empezar sino en perseverar"*

<< Leonardo da Vinci >>

*"El mundo es un lugar peligroso,  
no a causa de los que hacen el mal sino por aquellos  
que no hacen nada para evitarlo"*

<< Albert Einstein >>

*"La educación es el arma más poderosa  
que puedes usar para cambiar el mundo"*

<< Nelson Mandela >>





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refleja la opinión de sus autores y no representa en ningún caso las opiniones de la Unión Europea. La Comisión Europea no es responsable del uso que pueda hacerse de la información contenida. *Piratas del Plástico* también ha recibido el apoyo de la Fundación Española para la Ciencia y la Tecnología (FECYT) del Ministerio de Ciencia e Innovación y del Ministerio de Universidades en virtud del acuerdo de subvención FCT-22-18156. *Vigilantes del Suelo* es un proyecto de divulgación en ciencias sociales, impulsado conjuntamente por la Fundación Ibercivis y el Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA) y que cuenta con la colaboración de la Fundación Española para la Ciencia y la Tecnología FECYT - Ministerio de Ciencia e Innovación (acuerdo de subvención FCT-22-18723). Gracias también al Programa de Aprendizaje y servicio de la Universidad de Burgos.

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María Diez Ojeda

## Resumen

Las investigaciones de esta Tesis Doctoral se han realizado en el contexto de la asignatura de Educación Ambiental perteneciente al Área de Didáctica de las Ciencias Experimentales. Se trata de una asignatura optativa semestral orientada al alumnado de Grado en Maestro/a en Educación Primaria y Grado en Maestro/a en Educación Infantil. Para llevar a cabo los distintos estudios, se han diseñado previamente programas específicos que permiten lograr los objetivos y el desarrollo de las habilidades que se definen en la guía docente de la asignatura. Para ello, se han tenido en cuenta en todo momento los objetivos de la educación ambiental promulgados desde la UNESCO: proporcionar conocimientos sobre el medio ambiente biofísico, con sus complejidades intrínsecas y sus problemas, y lograr personas conscientes de cómo abordar la resolución de problemas, motivadas y responsables. En el **primer estudio** se realiza una investigación cualitativa sobre el conocimiento y apreciación del futuro profesorado sobre el uso educativo de la ciencia ciudadana. Esta investigación pone de manifiesto el gran desconocimiento del término ciencia ciudadana. Sin embargo, se percibe como una herramienta con un gran potencial didáctico cuya integración curricular produciría efectos muy beneficiosos en el desarrollo de las competencias generales del alumnado. El **segundo estudio** consiste en un análisis cuantitativo sobre el cambio en las actitudes ambientales tras la implementación de un programa de formación que incorpora actividades de ciencia ciudadana. Los hallazgos de esta investigación revelaron que se produjo una mejora de las actitudes ambientales del alumnado participante en todas las dimensiones de Preservación y Utilización. Por último, en el **tercer estudio**, se da un paso más en la concepción de la Educación Ambiental como Educación para el Desarrollo Sostenible, integrando como estrategia didáctica el Aprendizaje y servicio. Se realizó un análisis cuantitativo sobre el cambio en las actitudes hacia el Desarrollo Sostenible. Los hallazgos evidenciaron una mejora de las actitudes hacia el Desarrollo Sostenible en cada una de las dimensiones: *Medioambiente, Economía, Sociedad y Educación*. Así pues, esta tesis doctoral contribuye a la literatura científica en la Didáctica de las Ciencias Experimentales a través de los estudios realizados, que complementan la escasez de estudios existentes sobre la temática. Además, genera una línea de desarrollo de un marco metodológico para la integración curricular de la Educación Ambiental y la Educación para el Desarrollo Sostenible. Por último, como aporte para el profesorado, se describen las actividades desarrolladas a lo largo de la investigación, que pueden servir de guía para la elaboración de programas para la asignatura de Educación Ambiental.

**Palabras clave:** Educación Ambiental, Actitudes ambientales, Actitudes hacia el Desarrollo Sostenible, Aprendizaje y servicio, Ciencia Ciudadana, Formación del profesorado

## Abstract

The research for this Doctoral Thesis was conducted within the context of the Environmental Education course within the Experimental Science Teaching Area. This is a semester-long elective course aimed at primary and early childhood education students. To carry out the various studies, specific programs were previously designed to achieve the objectives and develop the skills defined in the course's teaching guide. To this end, the objectives of environmental education promulgated by UNESCO were consistently considered: to provide knowledge about the biophysical environment, with its intrinsic complexities and problems, and to develop individuals who are aware of how to approach problem-solving, motivated, and responsible. The **first study** conducted a qualitative study on prospective teachers' knowledge and appreciation of the educational use of citizen science. This research highlights the widespread lack of awareness of the term "citizen science." However, it is perceived as a tool with great educational potential, whose curricular integration would produce highly beneficial effects on the development of students' general competencies. The **second study** consists of a quantitative analysis of the change in environmental attitudes following the implementation of a training program that incorporates citizen science activities. The findings of this research revealed an improvement in the environmental attitudes of participating students in all dimensions of Preservation and Utilization. Finally, the **third study** takes a further step in the conception of Environmental Education as Education for Sustainable Development, integrating Service Learning as a teaching strategy. A quantitative analysis was conducted on the change in attitudes toward Sustainable Development. The findings showed an improvement in attitudes toward Sustainable Development in each of the dimensions: *Environment, Economy, Society, and Education*. Thus, this doctoral thesis contributes to the scientific literature on Experimental Science Teaching through the studies conducted, which complement the scarcity of existing studies on the subject. Furthermore, it provides a framework for developing a methodological framework for curricular integration of Environmental Education and Education for Sustainable Development. Finally, as a contribution for teachers, the activities developed throughout the research are described, which can serve as a guide for developing programs for the subject of Environmental Education.

**Keywords:** Environmental Education, Environmental Attitudes, Attitudes toward Sustainable Development, Learning and Service, Citizen Science, Teacher Training

## Listado de publicaciones

La presente Tesis Doctoral se presenta como compendio de artículos, como permite el Programa de Doctorado en Educación de la Universidad de Burgos. Los criterios del Programa requieren que, al menos, dos de los artículos que componen el compendio estén indexados en el *Journal Citation Reports* (JCR), pudiendo estar un tercero indexado en la base de datos de *Scopus*.

### Artículos publicados

A continuación, se presenta un listado de manuscritos que componen esta tesis que se encuentran publicados en el momento de la realización del depósito de la tesis.



1. Diez-Ojeda, M., Queiruga-Dios, M. y Queiruga-Dios, M. Á. (2024). Appreciation of primary preservice teachers about the potential educational use of citizen science in environmental education. *International Journal of Sustainability in Higher Education*, 25(9), 474-487. <https://doi.org/10.1108/IJSHE-03-2024-0184>

Artículo publicado en una revista indexada en JCR, cuartil Q1 dentro de la categoría *Education & Educational Research*, con un factor de impacto de 3.0.



2. Diez-Ojeda, M., Queiruga-Dios, M. y Queiruga-Dios, M. Á. (2024). Changing Spanish preservice teachers' environmental attitudes with a citizen science program integrated in Environmental Education subject. *European Journal of Education*, 59(4), e12746. <https://doi.org/10.1111/ejed.12746>

Artículo publicado en una revista indexada en JCR, cuartil Q1 dentro de la categoría *Education & Educational Research*, con un factor de impacto de 2.8.



3. Diez-Ojeda, M., Queiruga-Dios, M. y Queiruga-Dios, M. Á. (2025). Service-Learning in Environmental Education of Primary pre-service teachers: advancing SDGs and improving Attitudes towards Sustainable Development. *Education Sciences*, 15(1), 98. <https://doi.org/10.3390/educsci15010098>

Artículo publicado en una revista indexada en JCR, cuartil Q1 dentro de la categoría *Education & Educational Research*, con un factor de impacto de 2.5.

## Capítulos de libro

Además, como indicador de impacto de la investigación desarrollada en esta tesis doctoral, se indican los capítulos de libro y comunicaciones derivadas.

- ✓ **Diez-Ojeda, M.**, Canepa-Oneto, A., de la Fuente Gamero, P. y Queiruga-Dios, M.A. (2025 *en prensa*). Advancing SDG 14 Through a Service-Learning Initiative. En J. Vaquero et al. (Eds.), *Innovation, Resilience, Leadership and Sustainability in Higher Education*. Springer.
- ✓ de la Fuente Gamero, P., Canepa-Oneto, A., **Diez-Ojeda, M.**, y Queiruga-Dios, M.A. (2025 *en prensa*). Addressing SDG 15 from the University classroom: a vision from citizen science. En J. Vaquero et al. (Eds.), *Innovation, Resilience, Leadership and Sustainability in Higher Education*. Springer.
- ✓ **Diez-Ojeda, M.** (2025 *en prensa*). Uso de la inteligencia artificial para mejorar los modelos mentales del futuro profesorado sobre el ciclo del agua. En *La educación en la era de la tecnología: Desafíos y oportunidades*. Dykinson.

## Comunicaciones Orales

- ✓ **Diez-Ojeda, M.** (2024, noviembre). *Plastic Pirates Citizen Science Project* [Comunicación presentada en la International Conference EDUvision 2024: New contemporary challenges – Opportunities for integrating innovative solutions into 21st century education]. Conferencia en línea.
- ✓ **Diez-Ojeda, M.** (2025, febrero). *Transformative learning in environmental education* [Comunicación presentada en la International Conference EDUchallenge: Teaching challenges and evaluation of knowledge]. Ljubljana, Eslovenia.
- ✓ **Diez-Ojeda, M.** (2025, abril). *Uso de la inteligencia artificial para mejorar los modelos mentales del futuro profesorado de Primaria sobre el ciclo del agua* [Comunicación presentada en el II Congreso Internacional Futuro de la Tecnología en Educación: Revolucionando la educación. Nuevos modelos y espacios de aprendizaje con tecnologías (FUTUREDUCA 2025)]. València, España.
- ✓ **Diez-Ojeda, M.** (2025, junio). *Environmental education through the SDGs: A core axis in the STEAM approach* [Comunicación presentada en la International Conference EDUchallenge: Teaching challenges and evaluation of knowledge]. Ljubljana, Eslovenia.
- ✓ **Diez-Ojeda, M.**, y Queiruga-Dios, M. Á. (2025, septiembre). *El uso de la IA generativa para desarrollar el pensamiento crítico en la educación ambiental: Ciclo hidrológico* [Comunicación presentada en el 12.º Congreso Internacional sobre Investigación en la Didáctica de las Ciencias]. València, España.
- ✓ **Diez-Ojeda, M.**, y Queiruga-Dios, M. Á. (2025, septiembre). *Contribución del aprendizaje-servicio en educación ambiental a la formación de la profesión*

*docente* [Comunicación presentada en el 12.º Congreso Internacional sobre Investigación en la Didáctica de las Ciencias]. València, España.

## **Estancias**

Como requisito a la “Mención internacional”, se han realizados estancias de investigación predoctoral por un total de tres meses de duración en el Instituto Global de Altos Estudios en Ciencias Sociales, Santo Domingo, República Dominicana, bajo la tutorización de la Dra. Josefina Pimentel Valenzuela.



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# 1. Introducción

Nos encontramos actualmente inmersos en una gran crisis ambiental que es una consecuencia directa de la actividad humana. Los cambios producidos en el ambiente son especialmente visibles en las últimas décadas, llevando al entorno natural a una situación cada vez más difícil de revertir. Abordar este desafío global requiere una transformación profunda de las estructuras sociales y de los sistemas educativos, y orientarlos para alcanzar "El futuro que queremos" (Asamblea General, 2012, 2015; Leibniz, 2024). Para lograr este objetivo debe reconsiderarse *qué, dónde y cómo* aprendemos, de forma que las personas puedan adquirir el conocimiento, los valores y las actitudes, así como desarrollar las habilidades necesarias para tomar decisiones informadas que les permitan actuar, tanto individual como colectivamente, ante los desafíos y retos urgentes a nivel local, nacional y global. Cultivar una relación profunda con el entorno requiere que las autoridades educativas y el profesorado incorporen en la educación ambiental actividades prácticas que permitan tomar conciencia de las problemáticas ambientales locales y desarrollar un sentido de pertenencia a través de la participación en proyectos comunitarios (SEI y CEEW, 2022). Las Universidades e instituciones de educación superior pueden jugar un papel destacado en este proceso por su potencial como agente transformador de la sociedad y del medio ambiente a través de la generación y difusión del conocimiento y su capacidad de investigar el impacto de su actividad. Además, el surgimiento de nuevas metodologías y estrategias didácticas de innovación docente que promueven la efectividad del aprendizaje refuerzan este papel. Este enfoque está alineado con los compromisos asumidos en la Conferencia Mundial sobre Educación Superior de 2009, celebrada en la sede de la UNESCO en París (Ten, 2023; UNESCO, 2010), donde se destacó el papel de servicio comunitario de las instituciones de educación superior. En esta Conferencia se alentó a las instituciones educativas a promover el pensamiento crítico y la ciudadanía activa a través de un enfoque interdisciplinario que dé respuesta y se anticipe a las necesidades sociales y contribuya, así, al desarrollo sostenible.

La primera definición de Desarrollo Sostenible (DS) fue fijada por la Comisión Brundtland sobre Medio Ambiente y Desarrollo, refiriéndose a las estrategias que satisfacen las necesidades presentes sin comprometer la capacidad de las generaciones futuras para satisfacer las suyas (WCED, 1987). Este concepto de sostenibilidad se integra en el ámbito de la educación a través de la Educación para el Desarrollo Sostenible (EDS), cuyo objetivo es fomentar el desarrollo de competencias transversales en sostenibilidad del alumnado y mejorar las actitudes hacia el DS transformando su comportamiento. La EDS debe proporcionar al alumnado valores, conocimientos, habilidades y competencias que promuevan una vida sostenible y una participación en la sociedad. Es decir, la EDS debe centrarse en la transformación individual de cada estudiante, proporcionar el conocimiento necesario para tomar conciencia de la diversidad de realidades, fomentar la capacidad de análisis crítico y promover experiencias de vida que faciliten la conexión empática con distintas situaciones. La incorporación de este enfoque impulsará tanto el aprendizaje cognitivo como socioemocional, junto con una formación orientada a la participación comunitaria y la ciudadanía activa. Resulta, por tanto, imprescindible, incorporar el concepto de DS en todas las situaciones de aprendizaje para moldear la actitud y el comportamiento de los individuos y de la sociedad en su conjunto. Así, se hace necesaria una evaluación del grado de cambio en las actitudes y comportamientos en la vida de las comunidades e individuos a nivel local (UNESCO, 2005; 2019). Con la finalidad de adoptar cambios en todos los ámbitos, en septiembre de 2015, la Asamblea General de las Naciones Unidas adoptó la Agenda 2030 para el Desarrollo Sostenible. Esta agenda incluye 17 Objetivos de Desarrollo

Sostenible (ODS) que conforman un plan maestro para lograr un futuro sostenible para todos, ya que están interconectados y abordan los desafíos globales a los que se enfrenta la humanidad (Programa de las Naciones Unidas para el Desarrollo [PNUD], 2016).

Precisamente, el objetivo fundamental de la Educación Ambiental (EA), tal y como se señaló en la *Intergovernmental Conference on Environmental Education*, celebrada en Tbilisi en 1977, es lograr que las personas tengan la capacidad de comprender las complejidades inherentes al medio ambiente, así como las conexiones existentes entre los distintos sistemas que dan lugar a un todo, logrando que la sociedad procure el desarrollo propio en armonía con el medio ambiente. Para ello, la EA debe enfocarse hacia la acción y la resolución de problemas. Siguiendo este enfoque, se orientaron los objetivos de la educación ambiental hacia la creación de conciencia y sensibilización, el proporcionar conocimientos, fomentar las actitudes y desarrollar las habilidades necesarias para detectar y resolver problemas, involucrando a la ciudadanía. Igualmente se indicó en esta Conferencia que para el logro de los objetivos de la EA deben adaptarse las metodologías y materiales educativos a las necesidades de los estudiantes (Hoffmann, 1978). Así pues, la EA debe proporcionar al alumnado una comprensión del ambiente biofísico, ambos, el natural y el artificial, y de las problemáticas ambientales existentes en la actualidad. Pero, además, la EA debe proporcionar una motivación en las personas para resolver los problemas detectados. Para ello es necesaria la comprensión de las relaciones del ser humano con el entorno y comprender que el ser humano es una parte inseparable de un sistema global con la capacidad de modificar las relaciones entre las distintas partes. Como puede apreciarse, el objetivo de la educación ambiental va más allá de la conceptualización de medioambiente como el medio físico formado por una serie de sistemas desconectados. La EA debe mostrar una conceptualización del medioambiente como una diversidad de sistemas en continua interacción que se superponen en el mismo espacio físico, aunque se separan imaginariamente en muchas ocasiones para su análisis y estudio (Steele, 2010). Por tanto, una EA de calidad debe incorporar tres dimensiones: la educación sobre el medio ambiente; la educación en o a través del medio ambiente, y la educación para el medio ambiente (Türkoğlu, 2019). Para lograr este objetivo, tras décadas de reflexión y desarrollo de la EA, se han mantenido dos focos fundamentales: el uso de metodologías investigativas que involucren activamente al alumnado y el desarrollo de una ciudadanía activa, alfabetizada ambientalmente, y capaz de desarrollar un pensamiento crítico en torno a las cuestiones ambientales (Short, 2010).

La implementación de una educación ambiental de calidad adquiere mayor relevancia en el contexto de formación de futuro profesorado: es necesario que este posea unos conocimientos, habilidades y actitudes que permitan trasladar al aula los objetivos de la EA a través de secuencias de enseñanza-aprendizaje de calidad. Además, es necesario que esté capacitado para reinventar la EA a través de la innovación y aportar una visión global partiendo desde lo local. El diseño de estas secuencias de enseñanza-aprendizaje debe realizarse orientado a satisfacer las necesidades de desarrollo de su futuro alumnado y debe permitirles adquirir el conocimiento ambiental y, al mismo tiempo, desarrollar las habilidades y comportamientos ambientales (Ahi et al., 2017; Liu y Lin, 2015; Reid et al., 2021). La EA se presenta, por tanto, como algo necesario para toda la ciudadanía teniendo en cuenta que lo que no se conoce y no se comprende no se puede cuidar, además de como un insustituible instrumento para el DS (Acosta-Castellanos y A. Queiruga-Dios, 2022; Novo-Villaverde, 2009).

En este estudio de tesis doctoral se incorporan curricularmente en la asignatura de Educación Ambiental enfoques metodológicos orientados a favorecer una comprensión del ambiente como un sistema interconectado y comprender que el ser humano es una parte inseparable de un sistema global con la capacidad de modificar las relaciones entre las distintas partes. Al mismo tiempo, se generan contextos de enseñanza-aprendizaje que proporcionan el conocimiento necesario para tomar conciencia de la diversidad de realidades, fomentan la capacidad de análisis crítico y promueven experiencias de vida que facilitan la conexión empática con distintas situaciones. Con estrategias orientadas a la acción y a la búsqueda de soluciones, a la creación de conciencia y sensibilización, y al desarrollo de actitudes como precursoras de los comportamientos ambientales, y, al mismo tiempo, la adquisición del conocimiento científico propio de esta disciplina del ámbito de las Ciencias Experimentales. Se persigue así el objetivo de fortalecer la Educación, como pilar transversal y fundamental de la EDS.

Estos enfoques metodológicos con los que se ha desarrollado la programación de la asignatura de Educación Ambiental han sido la ciencia ciudadana y el Aprendizaje y servicio. Traslados a la educación formal, en el contexto de las ciencias experimentales, tanto la ciencia ciudadana como el Aprendizaje y servicio presentan puntos en común: las personas involucradas aprenden a través de la realización de una investigación y, al mismo tiempo, ofrecen un servicio a la comunidad, enfocando sus acciones en el logro de un reto real, que es el motor de las acciones.

### **1.1. Objetivos de la tesis doctoral**

El objetivo principal de esta tesis doctoral es realizar una contribución a la mejora de la educación ambiental que incorpore las tres dimensiones: educación sobre el medio ambiente; la educación *en o a través* del medio ambiente, y la educación *para* el medio ambiente, orientada a que el alumnado desarrolle unas habilidades y actitudes proambientales, utilizando enfoques metodológicos activos orientados a la resolución de problemáticas ambientales y sociales.

Los objetivos específicos de esta tesis doctoral son los siguientes:

1. Determinar el conocimiento previo del futuro profesorado con respecto al término ciencia ciudadana y conocer su apreciación con respecto al potencial educativo.
2. Analizar el cambio en las actitudes ambientales del futuro profesorado tras la participación en un programa de Educación Ambiental que incorpora actividades de ciencia ciudadana.
3. Analizar el cambio en las actitudes hacia el desarrollo sostenible del futuro profesorado cuando participan en un proyecto de Aprendizaje y servicio.

### **1.2. Descripción de los estudios realizados**

La investigación llevada a cabo en esta tesis doctoral abarca tres estudios recogidos en los tres artículos publicados.

### 1.2.3. Artículo Primero

En el primer artículo, titulado *Appreciation of Primary pre-service teachers about the potential educational use of citizen science in Environmental Education*, se investiga acerca del conocimiento que tiene el futuro profesorado con respecto al término de ciencia ciudadana y el potencial uso percibido para su incorporación al aula. Se diseñó un programa de enseñanza-aprendizaje, siguiendo la Teoría del Aprendizaje Experiencial (ELT) (Kolb, 1984; Kolb et al., 2001), que incorpora proyectos de ciencia ciudadana. La muestra se seleccionó siguiendo un criterio de conveniencia, participando 36 estudiantes, y se realizó un estudio mixto cualitativo-cuantitativo. Para ello se diseñó *ad hoc* un cuestionario previo sobre el conocimiento de la ciencia ciudadana y un cuestionario de aplicación posterior a la intervención, tras la participación en el programa de actividades de ciencia ciudadana. Los resultados iniciales muestran un gran desconocimiento sobre el término ciencia ciudadana, pero, tras la intervención, el alumnado percibe un gran potencial del uso de la ciencia ciudadana para el desarrollo de las competencias científicas, la alfabetización científica y las competencias genéricas. Además, perciben su potencial uso en las disciplinas científico-tecnológicas así como para la realización de proyectos interdisciplinarios dentro del aula. Se trata de un estudio exploratorio que confirma el uso potencial de la ciencia ciudadana para la didáctica de las ciencias experimentales y la educación para el desarrollo sostenible (Eugenio-Gozalbo et al., 2022; Peter et al., 2021), y además muestra su potencial transferencia al aula.

### 1.2.2. Artículo Segundo

El segundo artículo lleva el título de *Changing Spanish preservice teachers' environmental attitudes with a citizen science program integrated in Environmental Education subject*. Esta investigación analiza el efecto de la implementación de actividades de ciencia ciudadana en el programa de la asignatura de Educación Ambiental aplicando la Teoría del Aprendizaje Experiencial (Kolb, 1984; Kolb et al., 2001). Se utilizó el Inventario de Actitudes Ambientales (Milfont y Duckitt, 2010) para medir el cambio en las actitudes ambientales de 173 futuros maestros a través de un diseño experimental pretest-posttest sin grupo control. La participación en el programa formativo mejoró significativamente las actitudes ambientales en las 12 dimensiones definidas en el Inventario de Actitudes Ambientales. En todas las dimensiones se encontró un tamaño del efecto grande. Como conclusión relevante de este estudio se puede extraer que la incorporación de actividades de ciencia ciudadana en el programa de Educación Ambiental mejora significativamente las actitudes ambientales, existiendo un consenso sobre la importancia de las actitudes ambientales positivas como precursoras de los comportamientos proambientales (Bamberg y Möser, 2007; Liu et al., 2020).

### 1.2.3. Artículo Tercero

Por último, en el cuarto estudio, *Service-Learning in Environmental Education of Primary pre-service teachers: advancing SDGs and improving Attitudes towards Sustainable Development*, se da un paso más en la concepción de la Educación Ambiental para proyectarla hacia una Educación para el Desarrollo Sostenible. En esta ocasión, se utiliza el enfoque pedagógico definido por el Aprendizaje y servicio, que puede ampliar el enfoque y alcance social, con respecto a la ciencia ciudadana. Sin embargo, al igual

que ocurre con la ciencia ciudadana, las personas involucradas aprenden a través de la realización de una investigación y, al mismo tiempo, ofrecen un servicio a la comunidad, enfocando sus acciones en el logro de un reto real, que es el motor de las acciones emprendidas. Así pues, esta investigación analiza el efecto en el futuro profesorado de la implementación de un programa de Aprendizaje y servicio en la asignatura de Educación Ambiental. Además de evaluarse el proyecto con la rúbrica de Rubio-Serrano et al. (2015), se midió el cambio en Actitudes hacia el Desarrollo Sostenible (Biasutti y Frate, 2017) de 44 futuros maestros, considerando las dimensiones *Medio Ambiente, Economía, Sociedad y Educación*, como pilares de la Educación para el Desarrollo Sostenible (Ekpiken y Ukpabio, 2015; Biasutti y Frate, 2017). Se llevó a cabo mediante un diseño experimental pretest-posttest sin grupo control. La evaluación del proyecto de Aprendizaje y servicio fue favorable en todos los ítems (el propósito del proyecto, los aspectos formativos y los aspectos logísticos e institucionales) y se observó una mejora significativa de las actitudes de las personas participantes hacia el Desarrollo Sostenible en todas las dimensiones, no encontrándose diferencias significativas en función de la variable género. Se puede concluir que la inclusión del proyecto de Aprendizaje y servicio en el programa de Educación Ambiental mejora significativamente las actitudes hacia el Desarrollo Sostenible alineando la educación con los ODS. Esta investigación aborda la escasez de estudios científicos sobre el impacto de la participación de los futuros maestros en proyectos de Aprendizaje y servicio en el marco de los ODS en la mejora de su actitudes hacia el Desarrollo Sostenible. Asimismo, el estudio presenta claves metodológicas para integrar estas iniciativas en el currículo de la asignatura de Educación Ambiental, proponiendo una base para un posible marco alineado con la Educación para el Desarrollo Sostenible. Las actividades de Aprendizaje y servicio desarrolladas desde la educación superior suponen un avance significativo hacia los ODS. Además, al estar estos objetivos interrelacionados, el diseño de iniciativas de Aprendizaje y servicio permite abordar de forma integral y flexible los retos globales desde múltiples perspectivas, alineando la educación superior con el compromiso con la sostenibilidad. En este sentido, el mayor hallazgo de esta investigación se refiere a los beneficios académicos que produce la incorporación de la pedagogía de Aprendizaje y servicio, contextualizada en los ODS, para la promoción de la Educación para el Desarrollo Sostenible y para la mejora de todas las dimensiones de la Educación para el Desarrollo Sostenible: *Medio Ambiente, Economía, Sociedad y Educación*.

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**2. Artículo Primero: Appreciation of Primary pre-service teachers about the potential educational use of citizen science in Environmental Education**



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# Appreciation of primary preservice teachers about the potential educational use of citizen science in environmental education

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## Abstract

**Purpose** – This study aims to determine prior knowledge regarding the term “citizen science” (CS) and evaluate preservice teachers’ appreciation of the educational potential of CS.

**Design/methodology/approach** – Following the pedagogical framework of Experiential Learning Theory, a training program was designed for the subject of Environmental Education (EE) of the Primary

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*Ethics statement:* This study was approved by the Bioethics Commission of University of Burgos, with ethics approval reference IO 8/2024. Informed consent was obtained from the teachers and students, all of them aged 18 and above, who took part in the study granted explicit consent for the statistical analysis of their data.

*Data availability statement:* Data associated with this study will be made available on request.

*Declaration of competing interest:* The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Teacher Degree, incorporating CS activities. A quasi-experimental research was carried out with 36 primary preservice teachers who participated in this study, with a qualitative approach and without a control group. Two ad hoc surveys were defined for this study, the first one is related to prior knowledge about the term CS and a questionnaire was conducted to assess the educational potential of the CS after the implementation of the training program. The results showed a great initial lack of knowledge about CS but the appreciation of the preservice teachers after the educational intervention reveals the advantages and educational potential of CS.

**Findings** – Preservice teachers consider that CS can and should be incorporated, as part of the course syllabus, into the teaching system and this can be done in scientific-technological subjects or in all subjects with an interdisciplinary and transversal approach, with the majority of responses indicating that the development of generic skills would be the greatest perceived benefit for students.

**Originality/value** – There has been an increase in CS initiatives and projects in recent decades. However, despite the advantages for the participants and actors involved, its incorporation into higher education curricula is scarce.

**Keywords** Environmental education, Preservice teachers, Citizen science, Higher education, Elementary education

**Paper type** Research paper

## Introduction

The implementation of quality Environmental Education (EE) is especially relevant in the case of preservice teacher training. In this context, it must be considered that it is necessary for future teachers to have knowledge, skills and attitudes that can be transfer to the classroom through quality teaching–learning sequences. Furthermore, they need to be able to reinvent EE through innovation and provide a global vision starting from the local level. The design of these teaching–learning sequences must be aimed at meeting the developmental needs of children and must allow them to acquire environmental knowledge and, at the same time, develop environmental skills and behaviors (Ahi *et al.*, 2017; Liu and Lin, 2015; Reid *et al.*, 2021). EE is presented, therefore, as something necessary for all citizens, taking into account that one cannot take care of what one does not know and understand, as well as being an irreplaceable instrument for sustainable development (Acosta-Castellanos and Queiruga-Dios, 2022; Novo-Villaverde, 2009). Precisely, one of the benefits of participation in citizen science (CS) projects is related to the EE acquired by people who participate (Bonney *et al.*, 2009; Kenyon *et al.*, 2020; Peter *et al.*, 2021). CS enables the incorporation of research-based educational methodologies that results in an environmentally literate citizenry, with the ability to think critically, analyze environmental problems and work toward solutions (Short, 2010), in which each participant has the potential to become a principal researcher (Heigl *et al.*, 2019). Today, CS allows higher education institutions to expand their research areas and address problems that were initially beyond their reach, which is achieved by involving a large number of motivated people (Teo and Triantafyllou, 2020). CS can provide the necessary focus that EE requires (Green *et al.*, 2016) and the need for quality EE from an early age, directing this training toward action and problems (Hoffmann, 1978; Moseley *et al.*, 2010), for which, preservice teachers training plays a key role (Reid *et al.*, 2021). However, while there are educational experiences of integrating CS in the nonuniversity education curriculum (Calvera-Isabal *et al.*, 2023; Queiruga-Dios *et al.*, 2020), this is not the case in higher education, where informal learning is usually assumed and curricular integration is often absent (NASEM, 2018; Teo and Triantafyllou, 2020).

In this study, a teaching–learning program was designed for the EE subject for preservice teachers, following the Experiential Learning Theory (ELT) (Kolb, 1984; Kolb *et al.*, 2001),

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that integrates CS projects into the curriculum. This study aims to answer the following research questions:

- RQ1.* What is the prior knowledge of primary preservice teachers regarding the CS term?  
*RQ2.* What is the appreciation of preservice teachers regarding the educational potential of CS after participation in CS projects?

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### Theoretical framework

#### *Citizen science*

In general terms, CS is usually referred to describe scientific research activities in which the general public actively participates. Although this term was coined by Irwin in 1995 to describe a type of collaboration between nonexperts and specialist scientists around research (Irwin, 1995), its potential as a means of promoting public understanding of science was quickly seen (Bonney, 1996). Since then, there has been a great development of projects and practices under the umbrella of CS, particularly in recent decades, due, in part, to the great development of communication technologies, which facilitates the participation of people, data exchange and dissemination of projects and their results (López-Iñesta *et al.*, 2022; Newman *et al.*, 2012). Thus, various international programs have promoted the development and participation in CS projects and activities, such as the Horizon 2020 program of the European Union (EU), which has increased the number of funded projects in Science with and for Society (SwafS) (Wagenknecht *et al.*, 2021; Wehn *et al.*, 2020). This great development has resulted in the term CS not having a univocal definition and being used with different meanings depending on the different approaches or methods used, or which agents drive it (Fan and Chen, 2019; Haklay *et al.*, 2021; Heigl *et al.*, 2019). However, within the spectrum of CS definition, organizations such as the *European Citizen Science Association* (ECSA) seek to characterize the CS through the *ECSA's 10 Principles of Citizen Science for good practice* (Haklay *et al.*, 2020; Robinson *et al.*, 2018), which can be summarized as CS projects that actively involve people in scientific research. Moreover, a scientific result is produced, there is a benefit for all people, citizen scientists can participate in multiple stages of the process and receive feedback, they contribute to the democratization of science, data and metadata are made available to the general public, with the participants acknowledged in results and publications, they are evaluated for their political value and the impact produced, and project leaders take into account legal issues of intellectual property and the environmental impact. Assuming these ten principles, the *White Paper on Citizen Science in Europe* (Serrano-Sanz *et al.*, 2014) associates the term CS with the participation of all types of people, regardless of their training and profession, in activities related to scientific research. Thus, all people can contribute to CS actions, which, for some authors, represents a democratizing approach to science and scientific policies. This achieves the commitment of the people involved and causes changes in how people interact with each other and with the environment. The participation of the people involved can be of various types or at different stages or phases of the scientific process: bringing together teams, resources and partners, collecting and managing data through observation and measurement, performing calculations and analysis and even developing hypotheses or designing the methodology, to disseminating results and evaluating the program (Newman *et al.*, 2012).

CS therefore adds value to many scientific activities and links epistemic outcomes with societal values, producing benefits for participants related to personal growth, improvement in scientific literacy and enhancing positive attitudes toward science, as well as knowledge of environmental problems and fostering social innovation and policy impact (Bonney *et al.*,

2009; Vohland *et al.*, 2021). Furthermore, the CS is directly involved in the achievement of the Sustainable Development Goals (SDGs) of the 2030 Agenda (UN, 2015) because the data provided by the people involved serve to verify certain SDG achievement indicators (Queiruga-Dios *et al.*, 2020; Wehn *et al.*, 2020; Fritz *et al.*, 2019). Thus, CS is assuming an increasingly important role as a tool for science and engagement with the environment and environmental management (Curtis, 2018). The CS also presents great educational potential aligned with the new curricula of nonuniversity education (Calvera-Isabal *et al.*, 2023; Queiruga-Dios *et al.*, 2020), and likewise, it is considered that CS presents educational potential in the field of scientific education for EE and sustainability (Eugenio-Gozalbo *et al.*, 2022; Peter *et al.*, 2021).

#### *Citizen science in higher education*

Higher education institutions and libraries are increasingly organizing CS activities. On the one hand, the aim is to improve the transfer of science and innovation, but these activities are also designed with an educational purpose, as well as to raise awareness of certain environmental issues or to promote technical and social skills in innovation work (Teo and Triantafyllou, 2020). At the same time, CS projects engage students in research activities while addressing global challenges (Calvera-Isabal *et al.*, 2023). Universities can thus broaden their research areas and address problems that were not previously within their reach by involving a large number of motivated people and, on the other hand, it allows them to strengthen ties with society and enhance the university's position in society (Wylter and Haklay, 2018). However, in most cases, no educational methodology is designed for the implementation of CS activities and projects, considering that informal learning will occur by the mere fact of participation in such projects. Learning outcomes are also not routinely assessed, with the result that, to date, insufficient progress has been made in creating a pedagogical framework for CS integration (NASEM, 2018; Teo and Triantafyllou, 2020). However, it is possible to integrate CS projects in higher education, even if this entails some difficulties related to the role of the students in the project, which can often be limited to mere data collection and reporting, and also to the role of the teacher, who needs to be trained for its curricular integration (Eugenio-Gozalbo *et al.*, 2022; Nistor *et al.*, 2019; Roche *et al.*, 2020). In higher education, CS seems to fit perfectly with sustainability education and EE, following initiatives to present science and real-world problems, such as the Goals of Sustainable Development (Calvera-Isabal *et al.*, 2023; Kenyon *et al.*, 2020).

*Research goals.* The goals proposed in this research are the following:

- Determine the prior knowledge of preservice teachers regarding the CS term.
- To analyze the preservice teachers' appreciation of CS after participating in CS projects

## **Materials and methods**

### *Context*

This research was carried out in the subject of EE, which is taught in the fourth year of the Bachelor's Degree in Primary Education Teacher. It is a semester subject with an estimated workload of 125 h for students. The contents covered in this subject are: knowledge of basic aspects of ecology and the environment (ecosystems, biodiversity, the Earth and its layers, the atmosphere and environmental problems), analysis of causes and consequences of environmental problems, research on environmental problems and design of environmental projects for students. On the other hand, some of the teaching–learning objectives pursued by

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this subject are to identify some problems that affect the local and global environment; to understand the interrelation between society-science-nature and its implications in achieving a sustainable environment; to understand the interrelation of environmental problems by analyzing their causes and consequences and acquiring critical capacity to provide and/or evaluate possible solutions; and to design viable sequences of activities in the classroom, working on the EE in a transdisciplinary way (Diez-Ojeda *et al.*, 2024). To achieve the learning objectives of the subject, the program incorporates participation in CS projects. But also, taking into account that the participants are preservice teachers who must transfer what they have learned to the classroom in the future, the implementation of CS projects is accompanied by the design of a pedagogy according to the ELT formulated by David Kolb (1984). This theory focuses on experiential learning from an integrative perspective that combines experience, perception, cognition and behavior (Kolb *et al.*, 2001) and was applied by focusing this pedagogy on scientific practices (Lehane, 2020). Thus, students participated in the CS project following the cycle of data collection and observation, data analysis, drawing conclusions in the context of scientific literature and, finally, sharing and feedback from peers and teacher, from which new questions arise for future research arise.

The development of the programming of the EE program followed, in summary, the following stages (Diez-Ojeda *et al.*, 2024):

- Presentation of the contents of the subject. The subject and the contents to be covered during the course were presented. The students carried out activities, individually and in small groups, to search for information and debate.
- Presentation of CS projects. With the participation of an external expert, who gave a dissertation on CS and some examples of projects. The students were introduced to the CS projects in which they were going to participate and which are described below.
- Participation in CS projects, carrying out field activities in different parts of the city to take samples to determine the indicators defined in each project. Students participated in teams of four people.
- Sharing, debate, reflection and conclusions. Analysis sessions and drawing conclusions from the results found.
- Other activities related to works and exhibitions carried out by students.

In this case study, the CS projects implemented in the EE subject were “Plastic Pirates” ([www.plastic-pirates.eu](http://www.plastic-pirates.eu)) and “Vigilantes del suelo” [Soil Watchers] (<https://vigilantesdelsuelo.es/>). The CS Plastic Pirates project is developed in European rivers and aims to analyze the types of waste that can be found in different areas and riverbeds. The data collected regarding the type of waste and size is subsequently analyzed by expert scientists, making this information available to all interested people. On the other hand, the Soil Watchers project analyzes soil quality through physical, chemical and biological indicators, with the data obtained subsequently geolocated with the use of a smartphone app called Geonity (available at Google Play) so that these data is also available instantly for anyone who wants to consult them.

#### *Sample*

Convenience sampling was used to select the sample. In total, 36 students of the Bachelor’s Degree in Primary Education Teacher at the University of Burgos participated in the research. This research is based on a quantitative/qualitative approach.

### Instruments

All the participants were informed of the objectives of the study, and they provided their full permission for the case study to be published. To collect data, an initial questionnaire was used to determine the students' prior knowledge about the term CS. This questionnaire only contained two questions:

- (1) A1. Have you heard of the term “CS”?; and
- (2) A2. Try to define the term “CS” in a few words.

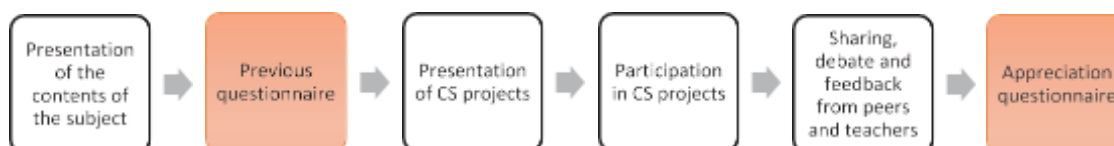
After completing the CS activities scheduled in the subject, the students answered another appraisal questionnaire on the potential of using CS in the classroom, designed *ad hoc*, which contained the following questions:

- B1. Do you think CS should be integrated into teaching curriculum?
- B2. Do you think CS can be integrated in the classroom activities?
- B3. In what subjects do you consider CS can be integrated in the classroom?
- B4. List the benefits that you think the curricular integration of CS can bring to students.
- B5. Would you integrate a CS project into the classroom?
- Justify, B6. Tell something that you have learned.

Questions B1 and B2 are similar, but they are intended to differentiate between the possibility of integrating CS into teaching and whether it should be integrated due to the educational benefits it produces in the participants. That is, the preservice teacher may find the implementation of an interesting activity but may consider that there are some types of difficulties in its implementation. [Figure 1](#) shows the use of the data collection instruments in the flow of the subject program.

### Data analysis

A quasi-experimental method was used in this study, with a qualitative approach and without a control group. In both questionnaires, designed *ad hoc* for this study, the percentage of affirmative and negative answers was analyzed for questions A1, B1, B2 and B5, whereas for the other questions (A2, B3, B4 and B6) a categorization was carried out after analyzing the responses. For this, a procedure based on grounded theory ([Glaser and Strauss, 2017](#)) was used to categorize the students' responses. In this sense, this section will show the methodological path followed in this research. Initially, the outcomes from the raw information were coded and categorized in two stages, open coding and axial coding ([Strauss and Corbin, 2002](#)). First, the texts of the responses were read in detail by the two main researchers to familiarize themselves with the content and to get a first understanding of the



**Source:** Authors' own work

**Figure 1.** Diagram on the different phases of data collection instruments according to the program flow

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themes and details, performing the microanalysis (sentence by sentence) of this data. [Figure 2](#) shows three fragments of the process followed in the open coding of the responses to question B4. Each concept obtained was associated with a color, corresponding to a specific category and subcategory.

The next step in this process was axial coding, which involves filtering the categories that have emerged in the previous stage. The information was reorganized creating new relationships between concepts. From among all the categories that emerged in the first phase of open coding, those that seemed most interesting were selected to further explanation. Selective coding allowed the identified categories to be grouped and integrated around a central category. In [Figure 3](#), the conditional matrix was integrated into the central category of benefits of CS integration, and the dynamic integration between the core category, the categories and the subcategories can be seen.

Once the process was completed, the results of the categorization are shown in [Table 1](#).

### Results

Regarding the first research goal of determining the prior knowledge of preservice teachers regarding the CS term, in the answers to the question A1, 60% of the participants responded affirmatively. However, when asked to try to define the term (question A2), only 20% provided answers related to the participation of professional nonscientists in research projects; the rest of the answers related CS with activities of scientific dissemination or bringing science closer to society, or define it as that scientific knowledge that citizens should possess.

With respect to the second goal of analyzing the preservice teachers' appreciation of CS after participating in CS projects, after the implementation of the training program designed in the subject of EE, the results are shown below.

To the questions B1, B2 and B5, all participants responded affirmatively. The results of the categorization of the responses to questions B3, B4 and B6 are shown in [Table 2](#).

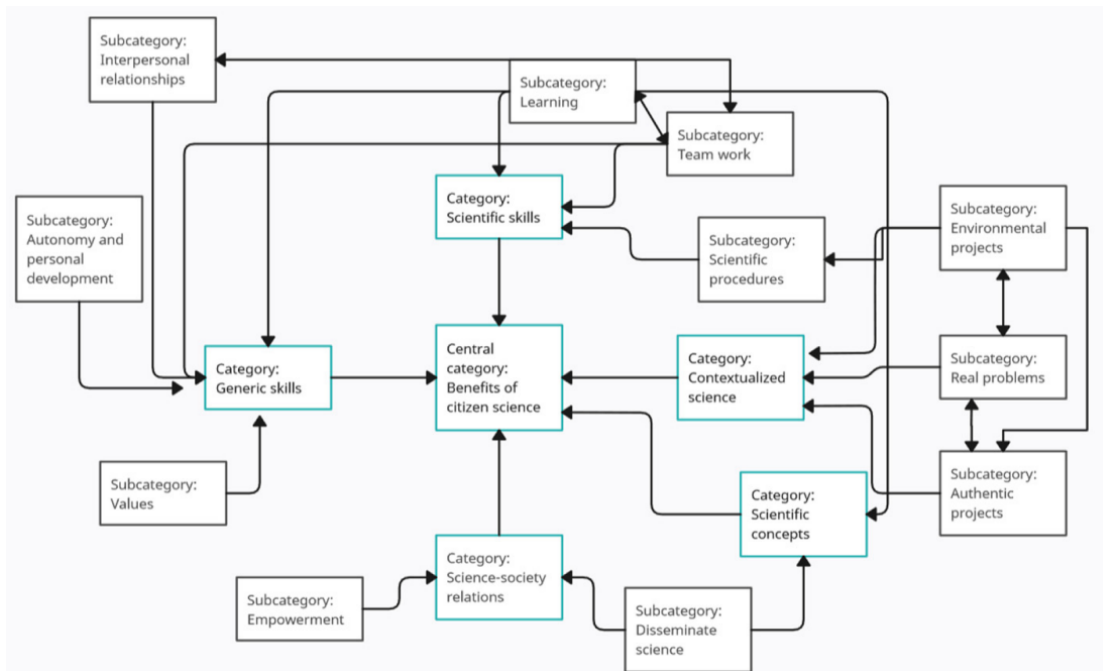
1. Some relevant aspects for students refer to group work, emotion management [development of generic skills-interpersonal relationships and group work], be part of a project learning about what scientific practices are like [scientific skills-procedural skills] and constructing learning [scientific concepts-construction], etc

2. Citizen science allows to improve the connection of science with society, improve the empowerment and collaboration of society [relations between science and society-explicit relationship]

3. Cooperative work is promoted [development of generic skills-interpersonal relationships and group work], students are involved in projects related to the real world [contextualized science-projects] fostering their commitment, camaraderie [development of generic skills-interpersonal relationships and group work]. In addition, real problems are approaching them, therefore, the student will become aware of these problems that are so present today, whether light pollution, noise pollution or that of rivers, seas, etc., and they will be part of this change, which results in an increase in your confidence [science and society relations - citizen participation] and desire to participate in more citizen science projects [development of generic skills-autonomy and personal development]

Source: Authors' own work

**Figure 2.** Open coding: fragments of the answers



**Figure 3.** Flowchart of the integration between core category, dimensions and subdimensions

As can be seen from the results, with respect to the question B3, the responses collected refer to the incorporation of CS in the scientific-technological disciplines (30.56%) or in an interdisciplinary way but organized from scientific-technological subjects (30.56%). Regarding the question B4, most of the answers collected refer to the development of generic skills (80.56%), to the fact that participation in CS projects allows to show contextualized and applied science (50.00%), and that, at the same time, it shows the relationships between science and society (50.00%); and, with regard to the question B6, the highest percentage of responses indicate the significance and potential educational use of CS projects (50.00%), followed by having known a large number of CS projects (30.56%), as well as the appreciation that there is no need to set limits to education by incorporating different approaches and activities in the classroom (30.56%).

Finally, it is indicated that the question B5 was not incorporated in the categorization because all the answers were affirmative and the justification of the answers, in all cases, referred to what was answered in question B4.

## Discussion

The idea of incorporating CS projects or activities into nonuniversity formal teaching to create teaching-learning activities is already reflected in scientific literature. This idea is motivated by the changes that these activities produce in the knowledge and behavior of the participants (Calvera-Isabal *et al.*, 2023; Queiruga-Dios *et al.*, 2020). Along these lines, this research shows the result of the implementation of a program for the EE subject of preservice teachers that incorporates CS activities. The goal of this program is to provide an EE about the environment, through the environment and for the environment (Türkoğlu, 2019). The design of the program has been carried out following ELT pedagogy, incorporating

**Table 1.** Categorization of the answers to the questions in the appreciation questionnaire

Question	Categories	Explanation
A2. Try to define the term "CS" in a few words	A2.1. Wrong definition	A totally different definition is indicated to the meaning of CS
B3. In what subjects do you consider that CS can be integrated in the classroom?	A2.2. Approximate definition	An approximate definition of CS is indicated
	B3.1. All subjects	CS can be integrated into all discipline syllabus
	B3.2. Natural sciences and mathematics	CS can be integrated into disciplines of natural sciences and mathematics
	B3.3. Scientific-technological subjects	CS can be integrated into disciplines of natural sciences, mathematics and technology
B4. List the benefits that you think the curricular integration of CS can bring to students	B3.4. Interdisciplinary approach	CS can be integrated interdisciplinary but starting from scientific subjects
	B4.1. Contextualized science	Students will perceive science applied to solve environmental problems
	B4.2. Generic skills	Students will develop generic skills
	B4.3. Scientific skills	Students will develop scientific skills
	B4.4. Scientific concepts	Students will learn and reinforce scientific concepts
B6. Tell something that you have learned	B4.5. Science-society relations	Students will understand connections between science and society
	B6.1. Large number of CS projects	Students have known about the existence of many CS projects
	B6.2. Put no limits on education	Do not set limits on the work that can be developed in the classroom and approaches that can be implemented
	B6.3. Meaning and use of CS	They have known the meaning of the term CS and how to apply it in the classroom
	B6.4. Empowerment	They have appreciated that participation in CS projects can produce empowerment

**Source:** Authors' own work**Table 2.** Results of the open questions B3, B4 y B6 according to the categorization made

Question	Categories	%
B3	B3.1. All subjects	19.44
	B3.2. Natural Sciences and Mathematics	19.44
	B3.3. Scientific-technological subjects	30.56
	B3.4. Interdisciplinary approach	30.56
B4	B4.1. Contextualized science	50.00
	B4.2. Generic skills	80.56
	B4.3. Scientific skills	30.56
	B4.4. Scientific concepts	11.11
	B4.5. Science-society relations	50.00
B6	B6.1. Large number of CS projects	30.56
	B6.2. Put no limits on education	30.56
	B6.3. Meaning and use of CS	50.00
	B6.4. Empowerment	19.44

**Source:** Authors' own work

experience, perception, cognition and behavior, adapted to scientific practices (Kolb, 1984; Kolb et al., 2001; Lehane, 2020).

The questionnaire prior to participation in CS activities reveals a great lack of knowledge of these projects on the part of the preservice teachers training (80% of the participants did not know how to define the object and meaning of CS). This result is obtained despite the great expansion that CS is having, gaining in the incorporation of actors and fields of action (Wagenknecht et al., 2021), and the great potential that CS has for EE (Peter et al., 2021). On the other hand, these results are consistent with the fact that CS activities are not reaching all sectors of society, with people with a higher level of education being the most involved in this type of projects (Haklay, 2018). The EE, as an instrument for sustainable development, needs the support of the socioeconomic, scientific-technological system, administrations and citizen networks (Novo-Villaverde, 2009). Thus, the creation of links between the EE and the CS could benefit both simultaneously. On the one hand, the CS would serve as a platform for environmental literacy, favoring the EE of society, and on the other hand, EE can use CS projects to transfer to society all the additional benefits of these projects to society.

With respect to the preservice teachers' appreciation of the educational potential of CS in education, analyzing the responses to the questions B1 and B2, and taking into account that all participants answered affirmatively, they clearly perceive this great educational potential. This educational potential of CS is qualified through the analysis of the rest of questions. Thus, for example, in the answers to the question B3, the analysis shows that the primary preservice teachers' appreciation is that CS projects can cover all school disciplines, although starting from scientific-technological disciplines. In terms of the benefits that they believe it can bring to their future students (question B4), they pointed out many of those that are evidenced in the scientific literature, such as the achievement of both generic and specific competences, the learning of scientific concepts (Eugenio-Gozalbo et al., 2022; Phillips et al., 2018; Queiruga-Dios et al., 2020; Roche et al., 2020) and the understanding of the existence of relationships between science and society (Calvera-Isabal et al., 2023; Haklay, 2018; López-Iñesta et al., 2022; Wyler and Haklay, 2018), and, at the same time, work on contextualized science and applied to real-world problems (Haklay et al., 2021). Finally, regarding the open-ended question on "tell something that you have learned," in addition to knowing the meaning of the term CS and its potential educational use, participants indicate that they have learned about the existence of many CS projects. Also, some responses pointed to the importance of not putting limits on education, in the sense of highlighting the importance of offering a diversity of educational options to students. From this response it could be inferred that participation in CS allows preservice teachers to appreciate the advantages of using active methodologies or proactive teaching-learning approaches. Furthermore, it indicates the empowerment provided by CS, which is also an advantage widely reported in the scientific literature (Haklay, 2018; Kenyon et al., 2020; Wehn et al., 2020). The results obtained are in line with those found in other studies conducted on active teachers, although in this case on secondary school students who participated in CS activities (Bracey, 2018). In the aforementioned study, the teachers involved reported a positive change in the student's perspective on how they see science and scientific practices, as well as their vision of the environment, and their feeling of having the ability to create science to improve the world.

In summary, it can be indicated that the learning of preservice teachers is relevant because, starting from a position of widespread ignorance of the term CS, they have detected the educational potential of integrating CS in their future classroom interventions, with the benefits that it entails.

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### Conclusion

This research has determined the prior knowledge of the term CS and has evaluated the preservice teachers' appreciation of the educational potential of CS after participating in a CS program in higher education. This program has been developed in the training of preservice teachers in the EE subject using the ELT pedagogical framework. This is especially relevant in teacher training because they have to acquire the pedagogical knowledge necessary for the application of EE in the classroom. In this context, future teachers, after participating in the designed activities, understand the meaning of CS and the implications for their future students of participating in CS projects.

The main findings of this research refer to the positive perceptions found in preservice teachers regarding the educational potential of CS. The integration of CS in university context achieves a double objective: on the one hand, it achieves a quality EE for students; on the other hand, as future teachers, it provides them with a tool with which to transfer to the classroom an applied and contextualized teaching related to the environment.

This study has implications for educational policies. In this sense, the authors would like to recommend to the educational authorities the creation of the necessary institutional frameworks for the incorporation of CS into the educational projects of university studies beyond EE. In this way, the educational advantages that CS brings to students, researchers and the institution itself can be transferred to university structures while at the same time strengthening ties with society. So, universities can use their potential and act as meeting points between educational, scientific, political and business institutions and favor the development of global networks. The study also presents implications for teacher training institutions and preservice teachers at nonuniversity levels, which can favor the design of resources and projects with which to generate quality EE adapted to students of all ages with the incorporation of CS. This training of preservice teachers and active teachers will favor the curricular integration of CS.

One of the limitations of the study is the small sample of students, so it would be advisable to carry out further studies with larger samples and in other contexts. Nevertheless, the study is a starting point from which to conduct qualitative studies related to the appreciation of preservice teachers regarding the benefits of incorporating CS in the classroom. Another limitation of the study is that it has been conducted in a specific context of the University of Burgos, so it does not necessarily describe trends present in other universities and in other countries. However, the results obtained may be of interest to other researchers and professors, who can use them as a starting point for further research and experiences.

Future lines of research will explore the advantages of incorporating CS projects into the curriculum in higher education on a permanent way. To this end, complementary activities will be designed around the CS project to enhance the desired learning objectives based on the subject syllabus and, in addition, to complement it with other educational approaches such as science, technology, engineering and mathematics (STEM), science, technology, engineering, arts and mathematics (STEAM) or Learning-Service, among others that allow incorporating other interdisciplinary learning objectives. Subsequently, it would also be interesting to analyze the change in the preservice teachers' appreciation of the educational potential of CS with the use of different educational approaches and methodologies. In this way the student's role will go beyond mere data collection and presentation, and thus presumably improve students' appreciation of the educational potential of CS. Another line of research will be aimed at the creation of a pedagogical framework that will allow the incorporation of CS in the university context, in the diversity of contexts and disciplines. Finally, longitudinal studies will be carried out to monitor how teachers trained with this approach transfer CS to the classroom and the results they obtain.

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**3. Artículo Segundo: Changing Spanish preservice teachers' environmental attitudes with a citizen science program integrated in Environmental Education subject**



# Changing Spanish preservice teachers' environmental attitudes with a citizen science program integrated in Environmental Education subject

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## Abstract

This research analyzes the effect of the implementation of citizen science activities in the Environmental Education (EE) subject program of the Degree in Primary Education applying Experiential Learning Theory. Environmental Attitudes Inventory (EAI) was used to measure the change in environmental attitudes (EA) of 173 preservice teachers through a pre-test–post-test experimental design without a control group. Participation in the training program significantly improved EA in the 12 dimensions defined in the EAI. Of the dimensions included in the second order factor *Preservation, Enjoyment of nature* reached the largest effect size and *Environmental movement activism* is the one that obtains the smallest effect size. With regard to Utilization, all dimensions presented a large effect size. No significant differences were found in EA based on the gender variable. It can be concluded that the incorporation of citizen science activities in the EE program significantly improves EA.

## KEYWORDS

citizen science, environmental education, Inventory of Environmental Attitudes, preservice teachers

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## 1 | INTRODUCTION

Environmental education (EE) aims to provide the knowledge and skills necessary to protect and improve the environment for all living beings, provoking a cognitive, affective and behavioural change that allows human beings to maintain their lives and, at the same time, conserve nature (Hudson, 2001; Moseley et al., 2010). UNESCO, in the document *The Contribution of early childhood education to a sustainable society*, refers to the importance of starting this EE at an early age and continuing throughout life (Samuelsson & Kaga, 2008). In addition, starting EE at an early age allows children to develop fundamental knowledge about the environment at a scientific level (Moseley et al., 2010). To achieve this, it is necessary for preservice teachers to acquire this training so that they can transfer it to the classroom appropriately. Therefore, it is necessary for students to understand the environment as a whole made up of different systems and elements interconnected with each other (Liu & Lin, 2015). This can be achieved by working in educational contexts that allow improving environmental attitudes, since positive attitudes towards the environment play a key role that is linked to pro-environmental behaviour (Heimlich & Ardoin, 2008). It can also be argued that citizen science favours, on the one hand, the acquisition of environmental knowledge by promoting greater confidence in addressing environmental issues and, in addition, improves participants' environmental attitudes (Ahi et al., 2017; Liu & Lin, 2015; Merenlender et al., 2016).

In this research, an activity program was designed for the subject of EE following the Experiential Learning Theory (ELT; Kolb, 1984; Kolb et al., 2000) that involves the participation of preservice teachers in citizen science activities. Subsequently, the change in environmental attitudes of the participants is measured. That is, this study aims to answer the following research question:

Does the implementation of a training program in EE that incorporates citizen science activities produce a positive change in the environmental attitudes of preservice teachers?

## 2 | THEORETICAL FRAMEWORK

### 2.1 | Environmental education

During the *Intergovernmental Conference on Environmental Education*, held in Tbilisi in 1977, it was pointed out that “the ultimate aim of EE is to enable people to understand the complexities of the environment and the need for nations to adapt their activities and pursue their development in ways which are harmonious with the environment” (Hoffmann, 1978, p. 12), starting from an action- and problem-oriented approach, and adapting methodologies and materials to the needs of students. Thus, the objectives of EE were categorised into: awareness and sensitisation, knowledge, attitudes, skills to detect and solve problems, and citizen participation. A few years earlier, Stapp et al. (1969, p. 34), had already indicated as the objective of EE as “producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution”. Thus, EE must help to understand that the human being is an inseparable part of a global system (human being, culture and biophysical environment) with the capacity to alter these relationships; and must provide an understanding of the biophysical environment, natural and artificial, as well as its role in today's society. EE also provides an understanding of existing problems and a motivation to solve the problems. From these first definitions, EE is not limited to the knowledge of the conceptualisation of the environment as the physical environment, but also includes the interactions between the different elements and existing systems. This orientation of the conceptualisation of the environment, as a set of systems and interactions that make life possible, is later reflected by UNESCO (Steele, 2010, p. 2) referring to the environment as “the product of both biophysical and social structures and processes, which we are a part of”. Thus, this EE must incorporate three dimensions (Türkoğlu, 2019): (1) EE as about environment; (2) EE as education in or through the environment; and (3) EE as education for the environment (Figure 1).

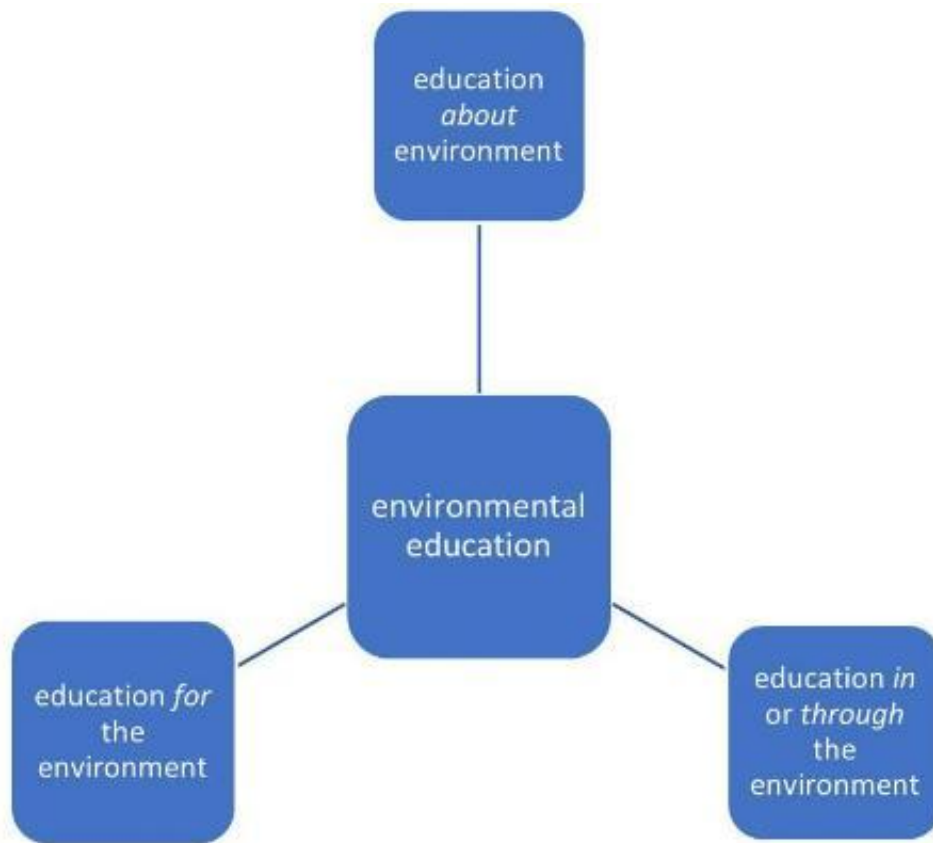


FIGURE 1 The three dimensions of environmental education (Türkoğlu, 2019).

In the case of preservice teachers and active teachers, it is of great importance that they have received adequate EE so that they can transfer this knowledge, skills and attitudes to the classroom and have the ability to create quality teaching-learning sequences. These teaching-learning sequences in EE must be designed to meet the developmental needs of children and enable them to acquire environmental knowledge, skills and behaviours (Ahi et al., 2017; Liu & Lin, 2015). In addition, they have the capacity to adapt and reinvent EE and to innovate from the local to the general issues (Reid et al., 2021).

Therefore, EE is presented as something necessary for all citizens, considering that what is not known cannot be taken care of. However, knowledge and even involvement in EE actions do not ensure a positive attitude towards the environment and pro-environmental behaviour either (West, 2015). A great obstacle for EE lies precisely in the interdisciplinary and multidimensional concept of the environment (Ahi et al., 2017; Barraza & Cuarón, 2004; Mason & Langenheim, 1957). However, there is agreement on the importance of positive environmental attitudes as precursors of pro-environmental behaviours (Bamberg & Möser, 2007; Liu et al., 2020).

## 2.2 | Environmental attitudes

Although attitude is a concept that admits various definitions depending on the psychological perspective with which it is approached (Crawley & Koballa, 1994; Zacharia, 2003), most researchers agree on the key aspect of the attitude construct as a tendency or internal state of the person. This tendency predisposes him/her towards favourable evaluative responses, if the attitude is positive, or unfavourable ones if it is negative; that is, “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor” (Eagly & Chaiken, 1993, p. 1). According to the three-dimensional model (Breckler, 1984), these responses when evaluating the entity can be cognitive (thoughts, knowledge, conceptions, stereotypes, tendencies, memories, ideas, convictions and beliefs), affective (favourable or unfavourable predisposition associated with this set, feelings of pleasure or displeasure) or behavioural (decisions and actions of approach or distance around said object), as well as overt or covert. So that attitudes

**TABLE 1** Multidimensional construction of environmental attitude (Milfont & Duckitt, 2010).

Second order factors	First order factors
Preservation	S1. Enjoyment of nature
	S2. Support for interventionist conservation policies
	S3. Environmental movement activism
	S6. Environmental fragility
	S8. Personal conservation behaviour
	S11. Ecocentric concern
	S12. Support for population growth policies
Utilisation	S4. Conservation motivated by anthropocentric concern
	S5. Confidence in science and technology
	S7. Altering nature
	S9. Human dominance over nature
	S10. Human utilisation of nature

influence people's responses towards some object, person or other aspects (Ajzen, 1989; Crawley & Koballa, 1994; Eagly, 1992). Although, currently, beyond the three-dimensional model, it is considered that affects, beliefs and behaviours are not a part of attitudes, but rather interact with them. Therefore, attitudes are considered as evaluative tendencies that can be inferred from and interact with affects, beliefs and behaviours (Albarracín et al., 2005); considering attitudes as evaluative reactions and interactions between these reactions (Dalege et al., 2016). In the field of environmental attitudes (EA), these could be defined, consequently, as a “psychological tendency expressed by evaluating the natural environment with some degree of favor or disfavor” (Milfont & Duckitt, 2010, p. 80). Following this contemporary approach to attitude structure, EA can be characterised through a multidimensional structure, with a horizontal structure or first-order factors and a vertical structure or second-order factors. Based on this conceptualisation, Milfont and Duckitt (2010) developed and validated the Environmental Attitudes Inventory (EAI), with a horizontal structure made up of 12 first-order factors or core dimensions, and a vertical structure made up of a single factor, *Generalized Environmental Attitudes*, or two correlated factors (Preservation, related to conservation and protection of the environment; and *Utilization*, related to the perception of mastery of the environment; Table 1).

In the EAI, these 12 scales or first-order factors contain a total of 120 items, 10 for each scale. Likewise, the authors developed other smaller versions, with 72 (EI-72) and 24 (EAI-24) items, the latter structurally validated by Ajdukovic et al. (2019). In this research, the EAI-24 has been used to analyse the change in environmental attitudes in preservice teachers. This questionnaire has been widely used in the scientific literature to analyse the change in EA with the incorporation of different methodological approaches in the EE programming of preservice teachers. Thus, for example, the use of problem-based learning (Kuvac & Koc, 2019), a transdisciplinary approach to EE in a literature subject (Martín-Ezpeleta et al., 2022), the participation in field work (Rachmatullah & Minsu, 2018) or carrying out literary activities of reading, analysis and creative writing of texts with an environmental theme (Martín-Ezpeleta & Echevoyen-Sanz, 2020). In this research, the participation and design of citizen science projects by preservice teachers were incorporated into the EE subject program.

### 2.3 | Citizen science

The term citizen science was coined by Irwin in 1995 to describe a type of collaboration between non-experts and specialist scientists around research. Thus, in the *White Paper on Citizen Science for Europe* (Serrano-Sanz et al., 2014) the term citizen science is associated with the participation of all types of people, regardless of their

training and profession, in activities related to scientific research. The participation of the people can be of various types or in different stages of the scientific process: from collecting data through observation and measurement, performing calculations and analysis, and even developing hypotheses or designing the methodology, to participation in the dissemination of the results. Thus, everyone can contribute to citizen science actions, which, for some authors, represents a democratic approach to science and scientific policies. This achieves the commitment of the people involved and causes changes in how people interact with each other and with the environment. The effect of citizen science on the participants is related to the improvement in scientific literacy (Bonney et al., 2009) and the improvement of positive attitudes towards science, also improving knowledge of environmental problems. Furthermore, citizen science participates in the achievement of the Sustainable Development Goals (SDG) because the data provided by the participants is useful to verify certain indicators of achievement of the SDG (Queiruga-Dios et al., 2020).

In this way, citizen science is assuming an increasingly important role as a tool for science and commitment to the environment and environmental management (Curtis, 2018), increasing the number of citizen science projects with the development of technologies, which facilitates the participation of people, the exchange of data and the dissemination of the projects and their results (Newman et al., 2011). Furthermore, citizen science has great educational potential aligned with the new non-university education curricula (Calvera-Isabal et al., 2023; Queiruga-Dios et al., 2020). Thus, environmental knowledge significantly affects environmental attitudes, which, in turn, affect environmental behavioural intention. However, to provoke behavioural changes related to environmental awareness, people need to find eco-friendly activities or specify how daily actions impact the environment (Liu et al., 2020).

### 3 | METHODOLOGY

#### 3.1 | Context

The context of this research is in the subject of EE that is taught in the fourth year of the undergraduate Degree in Primary Education Teacher, according to the structure of the study plan at the University of Burgos. It is a semester subject, with an estimated student workload of 125h. The contents of this subject are the following: knowledge of basic aspects of ecology and the environment (ecosystems, biodiversity, the Earth and its layers, the atmosphere and environmental problems), analysis of causes and consequences of environmental problems, research on environmental problems, and design of environmental projects for Primary Education students. Moreover, some of the teaching-learning objectives pursued by this subject are:

- Identify some problems that affect the environment, both locally and globally.
- Understand the interrelationship between society-science-nature and its implications in achieving a sustainable environment.
- Understand the interrelationship of environmental problems by analysing their causes and consequences and acquiring critical capacity to contribute and/or evaluate possible solutions.
- Design sequences of viable activities in the classroom working on EE in a transdisciplinary way.

The Theory of Experiential Learning was used to design the sequence of activities to be carried out as part of the EE program. The ELT focuses on learning through experience from an integrative perspective that combines experience, perception, cognition and behaviour (Kolb, 1984; Kolb et al., 2000). In this Experiential Learning, there are two key processes: experience and reflection on the experience (Dewey, 1938), so that students can develop solid theories that allow them to make decisions and solve problems. It is a dynamic vision of learning described as "a learning cycle driven by the resolution of the dual dialectics of

action/reflection and experience/abstraction” (Kolb & Kolb, 2009, p. 43), being present the experiential learning at all times of the activity. Thus, this model moves in a cycle of grasping experience, which includes Concrete Experience (CE) and Abstract Conceptualisation (AC); and transforming experience, with Reflective Observation (RO) and Active Experimentation (AE) (Lehane, 2020). ELT has been used as a pedagogical framework for the design of activity sequences for scientific learning (Lehane, 2020) and in the field of EE (Moseley et al., 2020). Figure 2 represents the ELT model cycle designed in the process of this research, with a strong scientific focus.

In this way, in the implementation of the program and after the initial phase of presentation of the contents, the focus of the subject was oriented towards citizen science. Thus, students actively participated in citizen science projects taking data on pollution indicators (CE), analysed the data and submitted it to debate, comparing the results between the groups and with what was found in searches in the scientific literature (RO). Figure 3 shows the future teachers on a field trip while participating in the citizen science project *Plastic Pirates* (<https://www.plastic-pirates.eu>) that studies pollution, and the type of plastics and microplastics present in surrounding rivers.

Subsequently, through collective debate, conclusions were obtained (AC). Following the same dynamic, they also participated in the citizen science project *Vigilantes del suelo* [Soil Watchers] (<https://vigilantesdelsuelo.es/>). In this case, participants took data on indicators of the state of soil health and interpreted the results.

Lastly, as a final activity, the students, in teams of four individuals, had to design a citizen science project that they could later implement in their future classroom with Primary students (AC). As part of the design of this citizen science project, students had to think about what environmental aspects they wanted to address and what environmental parameters they needed to study (for example, in the case of the *Plastic Pirates* project, the main goal was about analysing the type of waste found, its location and the size and quantity of the particles) and how data on these parameters would be collected, or what would be the origin of the polluting agent and what would be the consequences produced in the environment. All this considering that it must be a realistic plan that can be implemented in the future with Primary Education students and that involves young students so that the educational benefits of participation in a citizen science project (López-Iñesta et al., 2022; Queiruga-Dios et al., 2020). In summary, the workflow in the EE subject can be seen in Figure 4.

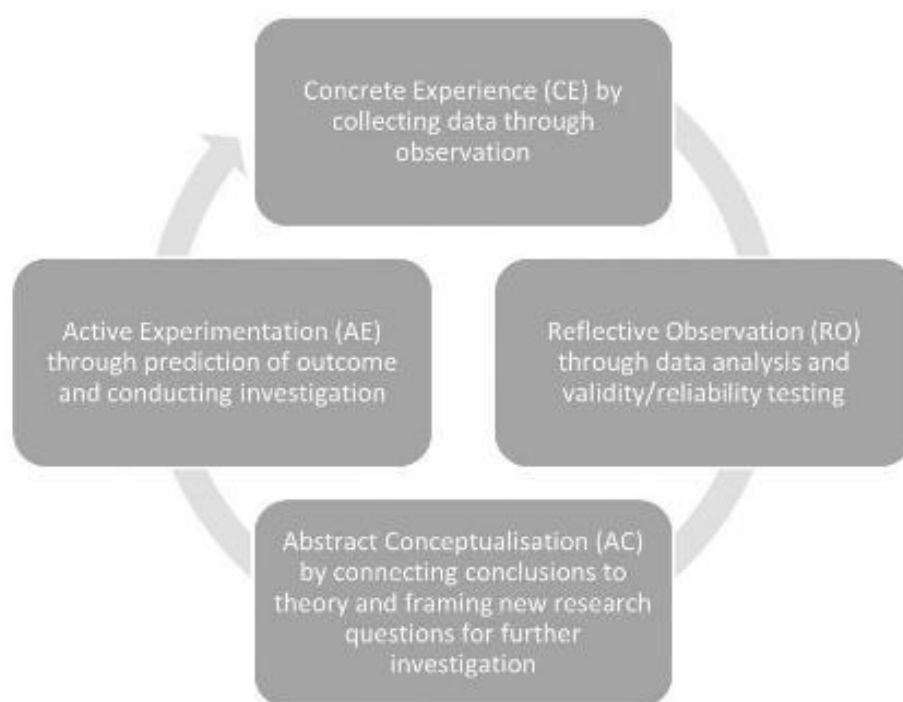


FIGURE 2 ELT model cycle focused on scientific practices adapted from Lehane (2020).

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FIGURE 3 Preservice teachers participating in the citizen science project Plastic Pirates. (a) Waste pickup. (b) Separation and classification of waste. (c) Data generation. (d) Waste sample.

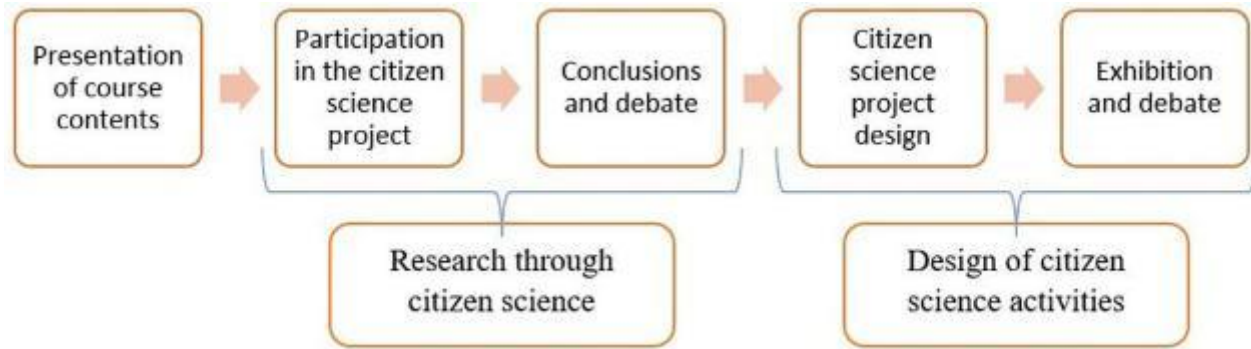


FIGURE 4 Workflow of the environmental education subject.

### 3.2 | Sample

Convenience sampling was used for the selection of the sample. The study sample was made up of 173 students, 138 girls and 35 boys from the Degree in Primary Education Teacher at the University. This research is based on the quantitative approach and has pre-test–post-test research design.

### 3.3 | Instruments

All the participants were informed of the objectives of the study, and they provided their full permission for the case study to be published. The EAI-24 was used to collect data (Milfont & Duckitt, 2010) for the measurement of environmental attitudes before and after the implementation of the learning program. The questionnaire uses a 7-point Likert-type scale, ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

### 4.4 | Data analysis

A before-and-after quasi-experimental design without a control group was applied. Data analysis was done by using the SPSS v.25 statistics package, which calculated the mean, the standard deviation, skewness, kurtosis, t-student and the Cohen's d coefficient. Skewness and kurtosis absolute values lower than 2 and 7, respectively, indicated no significant deviations from normality (West et al., 1995). Levene's test confirmed that in all cases the variances between the groups are equal ( $p > .05$ ). Subsequently, the t-test for independent samples was carried out in order to know the influence of the gender variable. To know the effect of the designed intervention program, a t-student test for related samples was carried out (Hernández-Sampieri et al., 2015) and the effect size was calculated (Cohen's d), taking into account that d between 0.2 and 0.3 represents a small effect value;  $d = 0.5$  means a medium effect value; and  $d \geq 0.8$  represents a large effect value (Cohen, 1992).

**TABLE 2** Descriptive statistics for the first- and second-order factors of the EAI pre-test–post-test, including the values corresponding to Preservation (P) and Utilisation (U).

Dimensions	Pre-test				Post-test			
	Mean	SD	Skewness	Kurtosis	Mean	SD	Skewness	Kurtosis
P	5.17	0.64	-0.16	0.54	5.46	0.45	0.32	0.37
S1	5.35	0.86	-0.18	0.74	6.05	0.62	-0.18	0.19
S2	5.43	0.82	-0.24	0.65	5.73	0.68	-0.04	-0.23
S3	5.24	0.80	-0.47	0.85	5.36	0.69	0.04	0.44
S6	5.28	0.78	0.36	-0.12	5.53	0.72	0.33	-0.29
S8	5.50	0.87	-0.73	2.55	5.73	0.77	-0.34	0.70
S11	5.57	0.87	-0.87	2.89	5.81	0.77	-0.42	0.82
S12	3.67	0.86	0.20	0.19	4.01	0.94	0.45	0.02
U	3.20	0.43	0.25	0.49	2.17	0.27	-0.06	0.54
S4	2.88	0.90	0.48	0.78	2.09	0.58	-0.01	-0.08
S5	3.73	0.67	0.26	-0.63	2.52	0.61	-0.71	-0.25
S7	3.50	0.71	0.19	-0.23	2.23	0.63	-0.22	-0.60
S9	2.55	0.74	0.35	-0.39	1.95	0.47	-0.16	1.60
S10	3.31	0.78	0.35	-0.16	2.07	0.62	0.11	0.09

## 4 | RESULTS

The results of the descriptive analysis (mean, standard deviation, skewness and kurtosis) for each first-order and second-order factor, both for the pre-test and the post-test, can be seen in [Table 2](#).

The values of skewness and kurtosis are less than 2 and 7, respectively, in absolute value, so the distribution does not deviate significantly from normality (West et al., 1995). Likewise, the average scores for the scales included in Preservation increase after the intervention and those of Utilization decrease. Thus, assuming the normality of the sample, the t-student test for independent samples was used to compare the mean scores based on gender ([Table 3](#)).

In order to analyse the change in environmental attitudes in the students, the t-test for related samples was carried out between the results of the pre-test and the post-test. In addition, the d-Cohen was obtained. The results are shown in [Table 4](#).

The result of the intervention shows a significant difference between the results of the pre-test and the post-test in all the dimensions of the EAI. Concerning the first order factors, there is a significant change in S1( $t(172) = 13.46$ ;  $p < .00001$ ), with an effect size of  $d = 0.93$ . In the scales corresponding to Utilization, in which the effect size is large: S4 returns  $t(172) = -10.85$ ,  $p < .00001$  and  $d = 1.05$ ; for S5,  $t(172) = -19.35$ ,  $p < .00001$  and  $d = 1.90$ ; for S7,  $t(172) = -25.17$ ;  $p < .00001$  and  $d = 1.90$ ; for S9,  $t(172) = -13.52$ ,  $p < .00001$  and  $d = 0.96$ ; and for S10,  $t(172) = -20.84$ ;  $p < .00001$  and  $d = 1.77$ . Regarding to the second-order factors, while for Preservation a medium effect size was obtained ( $d = 0.56$ ), for Utilization the effect size was larger ( $d = 2.87$ ).

## 5 | DISCUSSION

This research shows the programming of an EE subject for preservice teachers that incorporates the three dimensions that this type of training should seek: education about the environment, through the environment and for the environment (Türkoğlu, 2019). In the design of the program, a learning sequence has been defined following

TABLE 3 t-test for independent samples for gender for first- and second-order factors.

Dimensions	Pre-test			Post-test		
	t	df	p	t	df	p
P	-0.38	171	.705	-0.11	171	.909
S1	-0.41		.683	-0.12		.907
S2	-1.39		.166	-0.42		.677
S3	0.83		.409	0.42		.673
S6	-0.07		.944	0.11		.915
S8	-0.35		.730	-0.62		.540
S11	-0.43		.670	0.08		.469
S12	-0.16		.872	0.04		.968
U	0.92		.989	0.16		.874
S4	1.91		.357	0.08		.939
S5	-0.09		.932	0.07		.948
S7	1.22		.223	0.27		.790
S9	-0.71		.480	-0.25		.803
S10	-0.27		.791	0.13		.896

Note: The results show that there are no significant differences based on the gender variable ( $p < .05$ ) neither in the pre-test nor in the post-test.

$p < .05$ .

TABLE 4 t-test results for paired samples on pre-test and post-test, and effect size.

Dimensions	T	df	p	d
P	12.88	172	<.00001	0.56
S1	13.46		<.00001	0.93
S2	5.93		<.00001	0.40
S3	3.94		.00012	0.16
S6	5.71		<.00001	0.33
S8	6.41		<.00001	0.28
S11	5.50		<.00001	0.29
S12	6.54		<.00001	0.38
U	-33.19		<.00001	2.87
S4	-10.85		<.00001	1.05
S5	-19.35		<.00001	1.90
S7	-25.17		<.00001	1.90
S9	-13.52		<.00001	0.96
S10	-20.84		<.00001	1.77

Abbreviations: d, Cohen's d; df, degrees of freedom; p, p-value; t, t-test statistics.

$p < .05$ .

the ELT guidelines, combining experience, perception, cognition and behaviour (Kolb, 1984; Kolb et al., 2000). So that, based on experimentation in field activities, analysis and data collection, the student groups could draw conclusions. In each part of the process, there was feedback between groups and with the teaching staff to obtain

conclusions and reflections on environmental problems. Thus, participation in citizen science activities was taken as a real context to carry out the field trips, among whose benefits for the participants are changes in interactions with the environment and improvement in knowledge of environmental problems (Bonney et al., 2009; Queiruga-Dios et al., 2020). Based on the field trips, the students designed their citizen science project for future application with young Primary students, promoting quality EE at an early age since this design addresses the dimensions of education *about, in and for* the environment, with an action- and problem-oriented approach (Hoffmann, 1978; Moseley et al., 2010; Türkoğlu, 2019). To do this, university students had to conduct their own research, which was also subsequently exposed and defended, receiving feedback from classmates and teachers, thus closing the ELT learning cycle (Lehane, 2020). This approach is aligned with the vision of UNESCO (2021) indicating that EE must be a key component of educational curricula in 2025, and preservice teachers play a key role in this transfer (Reid et al., 2021).

Moreover, ELT and the development of outdoor field trips can be considered the basis for lifelong learning. It changes students' beliefs about the environment, as they improve their knowledge by interacting with the social, cultural, and physical environments around them. This study finds that ELT is an effective model for designing outdoor EE programs. Using ELT encourages collaborative practices, enhancing EE's effectiveness. By improving interactions between formal and informal educators within the ELT framework, outdoor field trips can become more comprehensive experiential learning experiences, thereby enhancing student learning (Moseley et al., 2020).

The research results show a significant improvement in environmental attitudes, with a medium effect size ( $d = 0.56$ ) for the second-order factor *Preservation*, but a large effect size ( $d = 2.87$ ) for *Utilization*. Thus, it could be indicated that, as a result of the application of the EE program, students have improved scores related to the need to preserve nature in its natural state and protect it against the use and alteration of human beings. However, the biggest change has occurred in *Utilization*, that is, the students, after the intervention, consider that it is less correct to take advantage of nature and modify it for human purposes. Related to this dimension, large effect sizes have been obtained in *Conservation motivated by anthropocentric concern* ( $d = 1.05$ ). Therefore, after the educational intervention, students perceive that environmental policies must prioritise the well-being of nature. Large values were obtained for several factors, such as *Confidence in science and technology* ( $d = 1.90$ ), that is, science and technology can repair and avoid environmental problems; *Altering nature* ( $d = 1.90$ ), that is, the environment must be preserved in its original state; *Human dominance over nature* ( $d = 0.96$ ), that is, the human being is not above nature; and *Human utilization of nature* ( $d = 1.77$ ), that is, environmental protection is a priority over economic development. However, in some studies preservice teachers were reluctant to prioritise nature conservation over economic development (Kuvac & Koc, 2019). Regarding the *Preservation* scales, one of the factors presented a large effect size, *Enjoyment of nature* ( $d = 0.93$ ), indicating a better attitude of students towards spending time in nature after the educational intervention.

Moreover, there is a dimension that has had the smallest effect size: *Environmental movement activism* ( $d = 0.16$ ). Despite having produced a significant change, which indicates that the effect produced by the educational intervention has not excessively enhanced the attitude towards environmental activism, in terms of getting involved in organised environmental actions. Nevertheless, this is in line with the fact that pro-environmental attitudes are not necessarily associated with a high degree of involvement in environmental activities (Carmona et al., 2021).

With respect to the gender variable, no significant differences have been found in environmental attitudes in any of its dimensions either before or after the educational intervention. However, in the scientific literature, several studies have been found in which the results show differences depending on the gender variable (Bergman, 2016; Domingues & Gonçalves, 2020; Fremerey & Bogner, 2015; Martín-Ezpeleta et al., 2022; Sutton & Gyuris, 2015; Tikka et al., 2010), but no significant differences were found in other studies according to gender (Carmona et al., 2021). This discrepancy in the results could be due to cultural and social differences between the samples participating in each investigation. On the one hand, EE is currently the objective of educational programs and as a consequence EA could tend to become homogenised (Carmona et al., 2021). However, many

of the research consulted are very recent studies, so more research should be carried out aimed at shedding light in this sense and determining if there really are differences in EA based on the gender variable or if there is any additional variable associated with it.

The authors want to highlight the benefits of incorporating citizen science in the EE training of preservice teachers. In addition to the improvement in the EA of the participants, citizen science projects are often designed by research institutions that support the development of the activities, so that the participants are collaborating in a global project in which data is obtained from different locations (López-Iñesta et al., 2022; Queiruga-Dios et al., 2020). At the same time, through the activities designed in the training program, preservice teachers acquire the ability to transfer this active EE to their future students through innovation and reinvention, thus responding to the call of the 3R: reimagine, recreate and restore EE (Reid et al., 2021).

In addition to the benefits that have been identified for both teachers and students, the training of EE leadership is another consequence of training preservice teachers, because they will be trainers in the future. Governments need to incorporate EE leadership into different statements, and this can start by schools. Implementing EE requires additional work from school' directors and adequate support from policy makers (Gan, 2021).

## 6 | CONCLUSIONS

This research addresses the gap in the scientific literature on how the participation of preservice teachers in citizen science projects improves the environmental attitudes of participants. But, at the same time, it incorporates the methodological keys for its integration into the curriculum of the EE subject, which could be the origin of a EE framework.

It has been proven how the incorporation of citizen science activities into EE programs significantly improves the EA of preservice teachers. Thus, citizen science can result in a key factor that allows the reinvention and updating of EE based on the analysis of specific environmental issues that affect the local community, and local communities in other locations, and that allow participants to acquire the knowledge of environmental problems as a global issue. In this sense, the recommendations for educational authorities are aimed at studying the creation of structures that favour the implementation of citizen science programs for the EE. This should be provided for all people and, in particular, for preservice teachers, as well as the creation of frameworks that favour research about the results of their implementation. This will also favour the transfer of programs related to the environment and citizen science to university education, given the educational potential that they are revealing in non-university and non-formal education.

EE must be part of the policy; otherwise, the environment will not be fully integrated into school agendas. The concept of EE leadership needs practical implications, such as promoting the implementation of EE in schools and the development of a sustainable vision that embraces the principles of sustainability and EE. It is important to identify the role of EE as a tool to achieve educational goals, a tool to address the environmental crisis, and a means to achieve both goals.

Particular attention should be given to the critical role that today's preservice teachers will play, as they will be responsible for the education of a significant proportion of young people in the future. Teachers play a key role in effective EE in the classroom and can influence children and youth's worldviews and attitudes, their interactions with the environment, their participation in decision-making, and their ability to make informed and responsible decisions. If teachers (or preservice teachers) lack knowledge, skills, or commitment, they are unlikely to succeed as leaders of environmental change in schools and produce environmentally literate students.

If teachers, as role models, are aware of the need to care for the environment, their students will be too. According to this research, it is crucial that future teachers reflect in their behaviour what they learn in EE classes.

Therefore, they should be trained as EE leaders and promote the idea that nature does not need people, people need nature. For a deeper understanding, the projects to be developed can include various activities that help future teachers find solutions to reduce environmental pollution.

As future avenues of research lines and with the purpose of reinforcing the results of this research, it would be advisable to carry out longitudinal studies to analyse the quality of the EE of the teachers participating in this program, when working with children at schools, and, also analyse the results of this education on the youngest students. The students participating in this research were preservice teachers and the research has been developed in the subject of EE. However, authors believe, and this is also a future line of research, that due to the large number of topics and themes covered by citizen science projects, as well as its practical and applied nature, citizen science can be incorporated into many other university studies. A citizen science project could even be developed between different subjects and/or different degrees or different universities so that citizen science would be integrated into the curricula. Incorporating citizen science into university curricula could also provide a framework for addressing the SDG.

### AUTHOR CONTRIBUTIONS

MAQD and MDO designed the research. MAQD and MDO designed and implemented the educational program and citizen science activities. MDO and MQD conducted the data analysis. MDO wrote the first draft of the manuscript. All authors contributed to manuscript writing, read and approved the final manuscript.

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### CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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**4. Artículo Tercero: Service-Learning in Environmental  
Education of Primary pre-service teachers: advancing  
SDGs and improving Attitudes towards Sustainable  
Development**



Article

# Service-Learning in Environmental Education of Primary Preservice Teachers: Advancing SDGs and Improving Attitudes Towards Sustainable Development

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**Abstract:** This research analyzes the effect of implementing a Service-Learning (SL) program in the Environmental Education (EE) subject of the Primary Education Degree. The SL project was evaluated and the change in Attitudes towards Sustainable Development (ASD) of 44 preservice teachers was measured, considering Environment, Economy, Society, and Education as dimensions, using a pretest-posttest experimental design with no control group. The assessment of the SL project was favorable in all items (the purpose of the project, the training aspects, and the logistical and institutional aspects) and a significant improvement in ASD was observed in all dimensions. No significant differences were found in ASD based on the gender variable. It can be concluded that the inclusion of SL projects in the EE program significantly improves ASD while aligning education with the SDGs.

**Keywords:** service-learning; sustainable development goals; education for sustainable development; sustainable development; environmental education; teacher training



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## 1. Introduction

The current climate crisis, along with other environmental sustainability issues, represents a direct consequence of human activities. The accelerated pace of these changes is leading to a massive loss of biodiversity, which is driving the extinction of thousands of species and altering fundamental natural cycles, degrading soils, and generating numerous social and economic consequences. These effects are even threatening the survival of our own species. In recent decades, the natural environment has changed at a rapid pace, producing impacts that are drastic, visible, and increasingly difficult to reverse. For example, two-thirds of the 1 °C global increase in temperature over the past 100 years has occurred since 1975. Furthermore, the annual extraction of renewable and non-renewable resources has nearly doubled since 1980, intensifying the negative impacts on the planet. It is estimated that one million species are currently at risk of extinction and that this loss, together with the lack of conservation of ecosystems, will have catastrophic consequences for both humanity and the environment (EEA, 2023; Hansen et al., 2010; IPBES, 2019; NAS, 2020; UNESCO, 2020). Facing this global challenge requires a profound transformation of current educational systems and social structures, so that the necessary changes are achieved to reach the goal of “The Future We Want” (General Assembly, 2012, 2015; Leibniz, 2024). It is therefore essential to reconsider what, where, and how we learn in order to develop the knowledge, skills, values, and attitudes necessary for all of us to make informed decisions and act both individually and collectively in the face of urgent challenges at local, national,

and global levels. To cultivate a deep relationship with the environment, educational authorities and educators must not only emphasize knowledge, but also incorporate practical skills, awareness of local environmental issues, and a sense of belonging through active participation in community projects (Diez-Ojeda et al., 2024a, 2024b; SEI & CEEW, 2022).

This comprehensive approach will enable students to engage meaningfully with their environment, fostering both a deeper understanding of ecological principles and a commitment to sustainable practices. In this process, higher education institutions and universities play a fundamental role due to their potential as transformative agents of society and the environment. Their role lies in the generation and dissemination of knowledge, as well as the ability to research the impact of their activity. This potential is strengthened by the emergence of new methodologies and teaching innovation strategies that foster learning effectiveness by actively involving students in teaching-learning processes and focusing on the development of competencies (Aramburuzabala & Cerrillo, 2023; Ashida, 2023).

The importance of developing skills is also highlighted in the European Council's recommendations on key competences for lifelong learning (EC, 2018). This document points out that "memorization of facts and procedures is key, but insufficient for progress and success. Skills such as problem solving, critical thinking, cooperation skills, creativity, computational thinking and self-regulation are more essential than ever in our rapidly changing society" (EC, 2018, p. 2). This approach is aligned with the commitments made at the 2009 World Conference on Higher Education, held at UNESCO headquarters in Paris (Ten, 2023; UNESCO, 2010), where the community service role of higher education institutions was highlighted. These institutions were encouraged to promote critical thinking and active citizenship through an interdisciplinary approach, responding to and anticipating social needs, and, in this way, contributing to sustainable development.

The first definition of sustainable development (SD) was established by the Brundtland Commission on Environment and Development, which conceptualized it as a strategy that meets the needs of the present without compromising the ability of future generations to meet their own needs (Aramburuzabala & Cerrillo, 2023; WCED, 1987). This concept of sustainability can be integrated into the field of formal education through Education for Sustainable Development (ESD). According to UNESCO (2017), ESD aims to foster transversal competences in sustainability in students and improve Attitudes towards Sustainable Development (ASD) by transforming their behavior. In this sense, ESD must be of a quality that equips students with values, knowledge, skills, and competences that promote sustainable living and active participation in society. Subsequently, in September 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs) and 169 targets. These SDGs replace the Millennium Development Goals as the reference framework for international development in the period 2015–2030. The SDGs are a blueprint for a sustainable future for all, as they are interconnected and address major global challenges such as poverty, inequality, climate change, environmental degradation, prosperity, peace, and justice (United Nations Development Program (UNDP, 2016)). In this context, Service -Learning (SL) is presented as a valuable tool to involve the university community in the challenges posed. This form of experiential learning takes place in practical environments and addresses social needs through activities designed to promote learning and the development of skills in students (Jacoby, 1996; Narong & Hallinger, 2023; Queiruga-Dios et al., 2021).

This manuscript presents the design and evaluation of a SL project developed in the Environmental Education (EE) subject, contextualized in the SDGs. In this project, students actively participate in the design and have decision-making power, which favors their involvement and commitment. Subsequently, the project was implemented in educational centers and associations. The project is specifically detailed oriented to SDG 13, "Climate

Action”, given the magnitude of climate change as a global challenge and its effects on all dimensions of sustainable development, including health, human well-being, food security, economic growth, natural resources, and biodiversity (UNESCO, 2024). In this context, the following research objectives are proposed:

- 1 Assess the developed SL project in terms of service, learning, and sustainability aspects.
- 2 Analyze the change in the ASD of the preservice teachers participating in the SL project.

## 2. Theoretical Framework

### 2.1. Service-Learning

Some studies (Sotelino-Losada et al., 2021) identify John Dewey as a key precursor of SL pedagogy. Dewey advocated constructivist experiential learning methodologies, promoting the “learning by doing” approach to solve problematic situations. Through this method, meaningful connections were established between the actions performed and their consequences, generating integrated and not isolated learning, which allows a holistic understanding of the relationship between actions and their effects. This process also facilitates the development of skills to act collaboratively, while promoting autonomous thinking and judgment (Dewey, 1916; Giles & Eyler, 1994; Narong & Hallinger, 2023; Sotelino-Losada et al., 2021). However, it was Robert Sigmon (1979) who, in a first attempt to formalize this methodology, formulated the three principles of Service-Learning. These principles hold that: (1) those receiving service should have control over the service; (2) as a result of experience, recipients should develop a greater capacity to serve and receive service; and (3) those providing service should simultaneously be learners, maintaining control over their learning process. Subsequently, Ehrlich (1996) developed a conceptual framework that defines SL as a pedagogy that establishes a strengthening link between community service and academic studies. This link is key to learning, as it allows interaction between knowledge and skills in real-world experiential contexts. Over time, various authors have enriched this definition of SL (Bringle et al., 2006; Felten & Clayton, 2011; Kuh, 2012). Thus, SL can be characterized by certain essential elements: it is a clearly defined, planned, and structured teaching-learning process, which facilitates both academic learning and the development of competencies in students, and it is oriented to the benefit of the community (O’Connor, 2012); it is based on collaborations and connections between various actors and communities (students, teachers, associations, educational institutions, among others) that share common objectives (Olberding & Hacker, 2015); it incorporates solid mechanisms for the evaluation of both learning and the impact generated (Queiruga-Dios et al., 2021; Rubio-Serrano et al., 2015; Salam et al., 2019); and it always includes moments and spaces dedicated to reflection (Furco, 1996; Sotelino-Losada et al., 2021).

The scientific literature strongly supports the multiple benefits that SL provides to students (Faulconer & Kam, 2023). These benefits include improved self-efficacy (Gutzweiler et al., 2022), the formation of civic attitudes (Ahmad & Gul, 2023), as well as an increase in self-esteem and motivation towards learning (Moyano et al., 2020). Additionally, participation in practical activities allows students to develop advanced problem-solving skills, which facilitates a deeper understanding of the social challenges in their environment (Arnold, 2022) and, in turn, translates into improved academic achievement (Gutzweiler et al., 2022).

The practice of SL is defined through three fundamental elements that characterize this type of educational project. First, it is established that the student must be the protagonist of both the learning process and the solidarity action, which implies that their active involvement is crucial for the success of the educational experience (Henderson & Hall,

1946; Basilico & Kelly, 2015). Second, it is essential that there is a clear intentionality to address and solve a real problem, which connects learning with authentic and relevant situations in the community (Faulconer & Kam, 2023; Gutzweiler et al., 2022). Finally, SL must be articulated with the curricular contents and competencies, ensuring that the activities carried out contribute to the development of the skills and knowledge established in the educational curriculum (Moyano et al., 2020; Queiruga-Dios et al., 2021).

From an institutional perspective, the SL approach also generates significant benefits, as it reinforces the image of the institution and contributes to greater student retention (Aramburuzabala & Cerrillo, 2023; Yob, 2011). These aspects have led to the widespread acceptance of SL pedagogy in higher education institutions. In America, these programs have been fully implemented for several decades. For example, in the 1920s, Antioch College integrated real-world experiences into its curriculum through learning and community-building strategies (Henderson & Hall, 1946; Queiruga-Dios et al., 2021). Likewise, SL pedagogy has a long tradition in Latin America and the Caribbean, where educational regulations and policies have included the promotion of student solidarity activities, both in schools and in higher education, establishing collaborative networks between educational institutions and the community (Basilico & Kelly, 2015; Tapia & Ochoa, 2015). More recently, this methodology has been adopted in European universities, gaining relevance thanks to the educational approaches promoted by the common European higher education area, as well as its contribution to the SDGs (Queiruga-Dios et al., 2021; Salam et al., 2019; Sotelino-Losada et al., 2021). Consequently, it is possible to affirm that few educational innovations have achieved such rapid and global success as SL (Deeley, 2016).

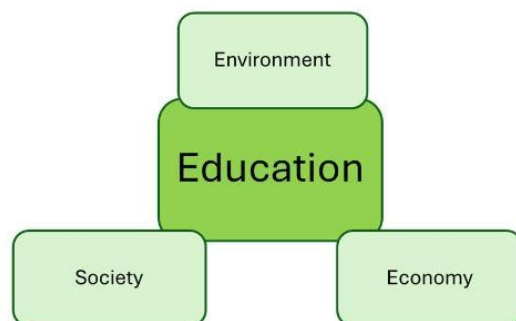
## 2.2. Service Learning, Sustainable Development Goals and Education for Sustainable Development

SL actions not only address specific issues such as the environment, inclusion, and inequalities, but also contribute to questioning the social order and ultimately promoting changes towards a more sustainable future. These actions provide a direct link to the SDGs, with SL being a key tool to advance them. SDG 4, Quality Education, is one of the most direct, as SL promotes inclusive and equitable education by integrating academic learning with community service, which in turn facilitates the development of socio-emotional competencies, values, and critical skills for the comprehensive training of students. This reinforces the educational approach focused on collective well-being and respect for human rights, aligned with transformative education. SL is also closely linked to SDG 17, "Partnerships for the goals", due to its collaborative approach. The success of SL depends on cooperation between various entities: universities, communities, NGOs, companies, and local governments. This collaborative network fosters synergies and the creation of alliances that jointly address social and environmental challenges (Rodríguez-Izquierdo, 2023; Salam et al., 2019). However, and despite the fact that the links between the different SDGs may not be directly evident (Vladimirova & Le Blanc, 2016), the SDG agenda explicitly emphasizes the importance of interdependencies both between and within the SDGs. The SDGs are conceived as an indivisible and integrated set that must be addressed in a balanced way, recognizing the interrelationships between them and between their social, environmental, and economic dimensions (Griggs et al., 2017; Kestin et al., 2017; Kroll et al., 2019; Leal-Filho, 2020).

Furthermore, SL is connected to ESD in that both approaches pursue the acquisition of knowledge and values oriented towards social action and environmental improvement. According to Eriksen (2013), ESD promotes the teaching of values such as equity, social justice, and citizen participation, principles that are also at the base of SL. This makes SL an educational practice that, while developing academic skills, encourages social responsibility and active participation in building a more equitable and sustainable society. Thus,

at the 2009 World Conference on Higher Education, held at UNESCO Headquarters in Paris (Ten, 2023; UNESCO, 2010), the role of higher education institutions in serving the community was highlighted, and they were encouraged to promote critical thinking and active citizenship through an interdisciplinary approach, responding to and anticipating the needs of society, and thus contributing to sustainable development.

ESD involves integrating the three fundamental pillars of sustainable development into educational processes: environment, economy, and society. This is achieved through empowerment and the promotion of democratic participation that harmonizes economic, environmental, and social aspects. In this context, it is essential to emphasize the transversal dimension that education constitutes (represented in Figure 1), given its key role in sustaining and balancing these pillars (Ekpiken & Ukpabio, 2015; Biasutti & Frate, 2017; Martín Bautista-Cerro et al., 2023). In this way, ESD becomes an integral element of the SDG regarding quality education and decisively enables the achievement of all other SDGs (Acosta-Castellanos & Queiruga-Dios, 2022). Thus, ESD must focus on the individual transformation of each student, providing them with the necessary knowledge to develop an awareness of various realities; fostering the capacity for critical analysis to understand their complexities; and promoting life experiences that facilitate an empathetic connection with different situations. In this way, both cognitive and socio-emotional learning will be promoted, together with training aimed at community participation and active citizenship. Therefore, it is necessary to incorporate the concept of SD in all learning opportunities to shape the attitude and behavior of individuals and society as a whole, requiring an assessment of the degree of change in attitude and behavior in the lives of communities and individuals at the local level (UNESCO, 2005, 2019, 2020). In this research, the Biasutti and Frate (2017) ASD questionnaire will be used.



**Figure 1.** Pillars of ESD. Own elaboration.

### 3. Methodology

#### 3.1. Sample and Context

The sample was selected using convenience sampling. The participants were 44 students (34 women and 10 men) from the Faculty of Education. This research is based on a quantitative approach and follows a pretest-posttest design with no control group.

The SL project presented as a case study was implemented in the EE subject, corresponding to the fourth year of Primary Education Degree. The SL design was made considering the needs detected in educational centers and in associations related to the teaching of EE from a SD orientation. This is a semester-long subject with a teaching load of 125 h. The curricular content of the course program covers fundamental topics such as the basic aspects of ecology and the environment, ecosystems, and biodiversity, the structure of the Earth and its layers, as well as the main environmental problems. In addition, it includes the analysis of the causes and consequences of these problems, research into them, and the design of environmental projects applicable to the primary education classroom.

The teaching-learning objectives of this subject are to identify the problems that affect the environment both locally and globally; to understand the interrelations between society, science, and nature and their role in building a sustainable environment; as well as to develop the ability to critically analyze environmental problems and propose possible solutions. Given the subject's focus on the training of preservice teachers, students are expected to acquire the necessary skills to design viable and transdisciplinary teaching sequences around EE (Diez-Ojeda et al., 2024a, 2024b).

Among the teaching-learning objectives pursued by the EE subject, the knowledge of the SDGs and the identification of situations to be addressed in the classroom stand out. In addition, it is sought that students acquire teaching-learning strategies that promote critical analysis and problem-solving skills in their future students, using the SL methodology indicated in the subject program. The skills that students are expected to develop are the following:

- Identify the most relevant environmental problems.
- Recognize the interrelations between society, science, and nature to contribute to sustainable development.
- Explain environmental problems (causes, consequences, and solutions) by designing and presenting projects.
- Apply the knowledge acquired in their future profession, demonstrating skills by developing and defending solid arguments, as well as solving problems in their field of study.
- Collect and interpret relevant data to formulate informed judgments, incorporating reflection on social, scientific, and ethical aspects.
- Communicate information, ideas, problems, and solutions clearly and effectively to both specialized and non-specialized audiences.

For students to achieve the competencies defined in the course program, they were assigned the task of designing learning scenarios in EE, with the intention of implementing them in educational centers through a SL program. These scenarios had to be contextualized around the SDGs. Among the 17 SDGs, those that have a direct relationship with environmental issues were selected, specifically:

- SDG 6: Clean water and sanitation.
- SDG 7: Affordable and clean energy.
- SDG 13: Climate action.
- SDG 14: Life below water.
- SDG 15: Life on land.

The selection of these SDGs is based on their thematic relevance to the EE subject and their direct connection with the environmental issues addressed in the classroom. To develop the activity, eight working groups were organized, made up of four or five students, in charge of designing a learning scenario that would favor the acquisition of significant learning in relation to environmental problems related to the selected SDGs. The planning of these scenarios was based on the Experiential Learning Theory (Hung et al., 2023; Kolb, 1984; Kolb et al., 2000; Narong & Hallinger, 2023), used as a pedagogical framework in the design of learning environments in scientific disciplines (Lehane, 2020) and in the field of EE (Diez-Ojeda et al., 2024a, 2024b; Moseley et al., 2020). This theory emphasizes learning through experience from an integrative perspective, with the purpose of students developing problem-solving skills. Based on Dewey's pedagogy (Dewey, 1938; Narong & Hallinger, 2023; Queiruga-Dios et al., 2021; Sotelino-Losada et al., 2021), the theory of experiential learning is structured around two essential processes: the experience of living

and critical reflection on it, which allows for a deeper and more critical understanding of the content worked on.

For the development of teaching-learning activities focused on a specific SDG, students were given the following instructions:

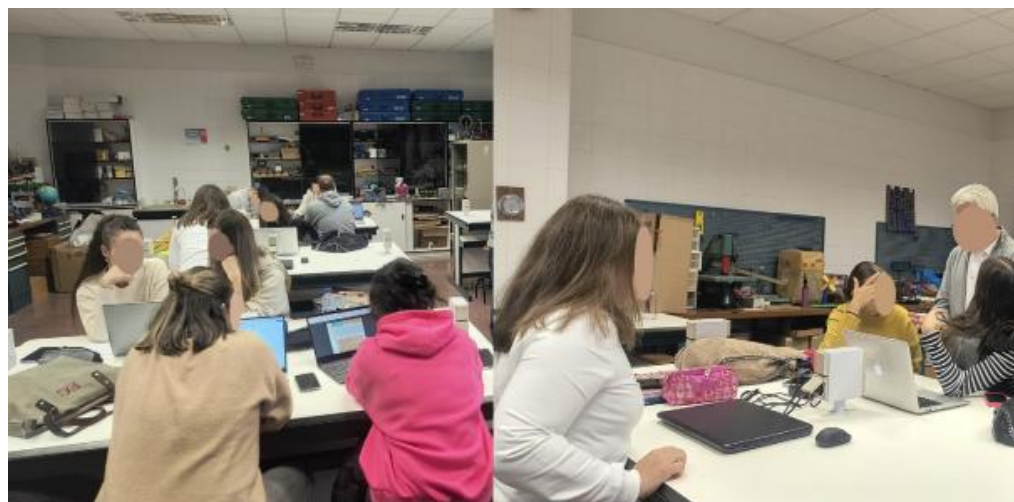
- **Linked to the curriculum:** The activities must be in line with both the educational curriculum of the school stage where it will be implemented and with the study plans of the participating school or association.
- **Context and duration of implementation:** The learning activities will be carried out in an educational centre or association and will have a total duration of 2 h.
- **Incorporation of scientific elements:** The design of learning activities must integrate scientific concepts and phenomena, which must be addressed through manipulative experiences that facilitate the understanding of the scientific foundations underlying environmental problems. These experiences must allow the construction of knowledge from direct observation and experimentation, promoting a deep understanding of natural processes and their relationship with environmental challenges.
- **Global understanding:** The design of learning scenarios should facilitate a comprehensive understanding of environmental systems and their interrelations, promoting a holistic view of environmental problems and solutions.
- **Social impact:** It is necessary to integrate educational components that make explicit the impact of environmental problems on human life, highlighting the social, economic, and health implications associated with these problems.
- **Encouragement of debate and reflection:** It should encourage debate and critical reflection, stimulating the active search for solutions and promoting student commitment to the topics addressed.

Subsequently, a draw was held to assign the SDGs to the different teams of students. The teams were given four sessions of two hours each to develop their projects, during which they received advice and guidance from the teacher. These sessions took place in the laboratory, a space designed to facilitate collaborative work and equipped with the necessary material for practical activities. The students used their own laptops to search for information, record activities and data, and prepare materials and presentations. In addition, the students must work on their projects outside the classroom. In this way, students have a space to work and interact with the teacher during the sessions and can adjust to the workflow by doing work at home. The teams were free to select the most appropriate activities, always in accordance with the established conditions. Later, in a fifth session, the activities were implemented in an educational center or in an Association. The workflow followed throughout the sessions is shown in Table 1.

**Table 1.** Workflow of sessions.

Session	Work Description
1	Presentation of the SL project. Assignment of SDGs to each team. Search for information on environmental issues.
2	Design of materials or scientific experiments related to environmental problems.
3	Analysis: global effect of environmental problems, impact on society, relationship with other SDGs. Development of teaching materials for transposition to the primary classroom.
4	Review and conclusion of the work: presentation in the classroom and feedback from classmates and teacher.
5	Implementation of teaching-learning activities.

Thus, in session 1, students are told what an SL project is, and they are informed that they are going to design a SL project. They are also given the instructions and conditions that the project must meet. Work teams are formed, and each team is assigned an SDG. Each working team is also given the characteristics of the target audience to which they should direct their intervention. Throughout this and the following sessions, there is continuous feedback from the teacher. The teacher answers questions from all the teams and makes suggestions. Sometimes, the teacher requires the attention of all the students to provide information that can be useful for all the teams. Afterwards, the students have time to search for information and guide their work (Figure 2).



**Figure 2.** Students work in teams and receive continuous feedback from the teacher.

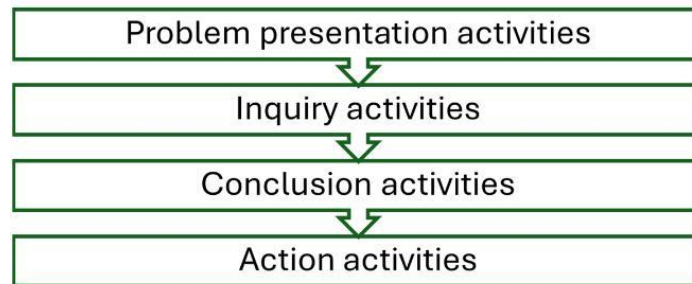
In session 2, students work in the laboratory with their laptops. They must design simple scientific experiments that are related to an environmental problem in connection with their SDG. The laboratory has materials to carry out experiments and, if required by a team, the teacher can provide the specific materials they need. Students can recreate experiments in the laboratory, or they can prepare them at home.

In session 3, students look for the relationship between local environmental problems and the global impact and how it affects society and how the achievement of the Goal they have assigned affects other Goals, based on the scientific experience they have designed. So, for example, if students wanted to conduct an experiment to model the effect of increased water acidity has on marine life, in relation to SDG 14 “Life below water”, they would also know the effects that this environmental problem has on humans, ecosystems, or economies, and which other SDGs it most directly affects. This will allow the students to learn about the connection between the SDGs and, therefore, they will be able to teach their future students about these connections. In addition, during this session, the teams prepare all the materials needed to implement the learning sequences (e.g., posters, models, or workbooks).

In session 4, the final review of the work takes place. All the teams present the work and materials developed and explain how they will be implemented in the classroom. They then receive feedback from their peers and the teacher.

Finally, during session 5, the students must put their teaching-learning activities into practice in the corresponding school or association. This phase is detailed below.

The implementation of the activities by the preservice teachers’ teams at the educational center or association, during a two-hour session, was organized following the workflow detailed in Figure 3.



**Figure 3.** Flow of implementation of activities.

As an example, activities adapted to environmental themes linked to SDG 13, Climate Action, are described below:

- **Problem-solving activities:** The preservice teachers presented a self-made model of different ecosystems. Through questions, the children were asked to identify relationships between ecosystems and reflect on the factors that can lead to increased temperatures and their influence on natural systems. Although the conclusions were simple, the main objective was for the students to understand the interconnectedness of the planet and the global effects of environmental changes. It was also intended to provide a preparatory context for the questions they would ask during the inquiry activities.
- **Inquiry activities:** Two inquiry experiments were conducted so that students could explore how certain factors affect the climate and some of the consequences of rising temperatures:
  1. **Effect of CO<sub>2</sub> concentration on the greenhouse effect:** This activity consists of measuring how the greenhouse effect increases as the concentration of carbon dioxide increases. To do this, a glass of water and a thermometer are placed in an airtight container, and the same is done with another glass of water and its thermometer, placing it in a container identical to the previous one, but in which a carbon dioxide atmosphere has been generated (by making acetic acid react with sodium bicarbonate). Both containers are placed in the sun or under a high-intensity light source. Observation of the thermometers allows participants to draw conclusions.
  2. **Rising water temperature:** In this experiment, a specific volume of water was measured and then heated until it was close to boiling point. During the process, it was observed that the volume of water increased as the temperature rose. This phenomenon led the students to conclude that warming causes water to expand. A debate was then opened on the effects of rising temperatures on the oceans, with particular emphasis on how this warming contributes to rising sea levels, an environmental problem related to climate change.
- **Conclusion activities:** Based on the previous activities and through directed questions, students were guided to identify the relationships between the increase in global temperature and its effects on human life and ecosystems.
- **Action activities:** Finally, students were invited to reflect on individual actions that could mitigate the effects of climate change, formulating and discussing proposals. Some of these ideas were selected, some of which were suggested by the preservice mteachers, and a collective commitment was drawn up to promote respectful attitudes towards the marine environment, concluding with the creation and signing of a manifesto in defense of the fight against climate change.

### 3.2. Instruments

All the participants were informed of the objectives of the study, and they provided their full permission for the case study to be published.

The rubric of Rubio-Serrano et al. (2015) was used to assess the Service-Learning project. This rubric includes 11 dimensions related to the project's purpose (social needs, service, social meaning, and learning), the formative aspects (participation, group work, reflection, recognition, and evaluation), and the logistical and institutional aspects (partners, consolidation, and institutions). Each dimension can be assessed at four levels according to the degree of development achieved by that dimension in the project.

To measure ASD, the Biasutti and Frate (2017) questionnaire was used. The questionnaire uses a 5-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). This instrument is detailed in Table 2. It offers a significant advantage over previous questionnaires, since, in addition to addressing the three classic dimensions of environment, economy, and society (Michalos et al., 2011; Olsson et al., 2016; UNESCO, 2006), it incorporates the educational dimension as a transversal pillar. Its structure of twenty items, five for each of the four dimensions, facilitates its application, in addition to having been validated with a university population, which makes it particularly suitable for the context of this study.

**Table 2.** Biasutti and Frate (2017) ASD questionnaire.

Dimensions	Item Code	Item
Environment	E.1	When people interfere with the environment, they often produce disastrous consequences.
	E.2	People's quality of life is directly linked to environmental protection.
	E.3	Biodiversity should be protected at the expense of industrial agricultural production.
	E.4	Infrastructure development is less important than environmental protection.
	E.5	Environmental protection is more important than industrial growth.
Economy	Ec.1	Government economic policies should increase sustainable production even if it means spending more money.
	Ec.2	People should sacrifice more to reduce economic differences between populations.
	Ec.3	Government economic policies should increase fair trade
	Ec.4	Government economic policies should act if a country is wasting its natural resources.
	Ec.5	Reducing poverty and hunger in the world is more important than increasing the economic well-being of the industrialized countries.
Society	S.1	Each individual should do a lot to keep the peace in the country.
	S.2	The society should further promote equal opportunities for males and females.
	S.3	The contact between cultures is stimulating and enriching.
	S.4	The society should provide free basic health services.
	S.5	The society should take responsibility for the welfare of individuals and families.
Education	Ed.1	Teachers in educational institutions should use student-centered teaching methods.
	Ed.2	Teachers in educational institutions should promote future-oriented thinking in addition to historical knowledge.
	Ed.3	Teachers in educational institutions should promote interdisciplinary between subjects.
	Ed.4	Teachers in educational institutions should promote the connection between local and global issues.
	Ed.5	Teachers in educational institutions should promote critical thinking rather than lecturing.

### 3.3. Data Analysis

The assessment of the SL project involved the participation of two external experts of the Service-Learning Program of the University of Burgos. These experts, through analysis of the project design and interviews with the student teams, completed the evaluation rubric (Rubio-Serrano et al., 2015), awarding their grades independently. Subsequently, the experts met with one of the authors to clarify certain aspects of the process and reach a final consensus on the evaluation of the project.

A before-and-after quasi-experimental design without a control group was applied. Data analysis was conducted using the SPSS v.25 statistics package, which calculated the mean, the standard deviation (sd), skewness, kurtosis, t-student (t-test for independent samples to know the influence of the gender variable and t-test for related samples between the pretest and the posttest), and the Cohen's d coefficient. Because the sample are less than 50 individuals, the Shapiro–Wilk test was applied to determine if the data shows a normal distribution (de Souza et al., 2023; Royston, 1983). The Shapiro–Wilk test indicated that the difference between the data sample and the normal distribution is not statistically significant ( $W(44) = 0.9534$ ,  $p = .0734$ ; Skewness = 0.1558; Excess kurtosis =  $-0.07747$ ). Levene's test confirmed that in all cases the variances between the groups are equal ( $F = 3.04331$ ;  $p > .05$ ). Subsequently, the t-test for independent samples was carried out to determine the influence of the gender variable. To determine the effect of the designed intervention program, a t-student test for related samples was carried out (Hernández-Sampieri et al., 2015) and the effect size was calculated (Cohen's d), taking into account that d between 0.2 and 0.3 represents a small effect value;  $d = 0.5$  means a medium effect value; and  $d \geq 0.8$  represents a large effect value (Cohen, 1992).

## 4. Results

To determine whether the designed project meets the specifications to be a SL project, the evaluation rubric of Rubio-Serrano et al. (2015) was used. Figure 4 shows the result of the project evaluation in each of the items assessed, using the spider chart to represent the results of the rubric.



**Figure 4.** Spider chart with the result of the SL project assessment.

The rating of all items shows a score of 3 or 4, with the items of Service, Learning, Participation, Reflection, Acknowledgment, and Assessment reaching the maximum score of the rubric, indicating an appropriate design for the SL project.

The results of the descriptive analysis (mean, standard deviation) for the pre-test and the post-test can be seen in Table 3.

**Table 3.** Descriptive statistics.

Dimensions	Pre-Test		Post-Test	
	Mean	sd	Mean	sd
<i>Environment</i>	3.44	0.24	3.97	0.24
E.1	2.61	0.49	3.21	0.46
E.2	3.93	0.81	4.39	0.49
E.3	3.18	0.50	3.73	0.66
E.4	3.77	0.42	4.25	0.44
E.5	3.68	0.52	4.30	0.46
<i>Economy</i>	3.76	0.51	4.26	0.26
Ec.1	3.73	0.59	4.18	0.39
Ec.2	3.71	0.51	4.23	0.42
Ec.3	3.71	0.55	4.27	0.45
Ec.4	3.80	0.59	4.27	0.45
Ec.5	3.84	0.65	4.32	0.47
<i>Society</i>	4.27	0.35	4.51	0.30
S.1	3.91	0.64	4.39	0.49
S.2	4.34	0.48	4.55	0.50
S.3	4.46	0.50	4.66	0.48
S.4	4.50	0.51	4.71	0.46
S.5	4.16	0.37	4.27	0.45
<i>Education</i>	4.11	0.20	4.38	0.25
Ed.1	3.64	0.53	4.11	0.32
Ed.2	4.05	0.57	4.27	0.45
Ed.3	4.32	0.47	4.43	0.50
Ed.4	4.18	0.39	4.57	0.50
Ed.5	4.39	0.49	4.50	0.50
Total	3.89	0.19	4.28	0.14

Note. sd = standard deviation.

The results of the descriptive analysis show initial scores that exceed the mean score for each item, with an increase in mean values in all dimensions after the intervention. The magnitude of this change is detailed below. Thus, assuming normality of the sample, the t-student test for independent samples was used to compare the mean scores as a function of on gender (Table 4).

**Table 4.** t-Student test for independent samples for gender.

Dimensions	Pre-Test			Post-Test		
	t	df	p	t	df	p
<i>Environment</i>	0.06	41	.478406	1.33	41	.09624
E.1	−0.87		.206482	−1.63		.055881
E.2	0.30		.384142	0.10		.461025
E.3	0.13		.448374	−0.69		.247141
E.4	0.23		.410039	0.41		.343169
E.5	0.13		.450649	0.81		.210784
<i>Economy</i>	0.18		.429993	−0.48		.316411
Ec.1	0.44		.330072	0.17		.434579
Ec.2	−0.03		.487421	−0.23		.410039
Ec.3	−0.03		.488416	−0.58		.283775
Ec.4	0.03		.489207	0.26		.415269
Ec.5	0.33		.372964	0.62		.269233

Table 4. Cont.

Dimensions	Pre-Test			Post-Test		
	t	df	p	t	df	p
<i>Society</i>	1.56		.063178	1.52		.067715
S.1	1.07		.144414	0.83		.206482
S.2	1.20		.118500	1.11		.137369
S.3	1.04		.152183	1.06		.147906
S.4	0.71		.241703	0.74		.231676
S.5	1.39		.086746	1.02		.157562
<i>Education</i>	1.58		.060322	0.98		.165205
Ed.1	-0.24		.404568	-0.15		.440327
Ed.2	0.34		.367235	1.02		.157562
Ed.3	0.62		.269233	0.49		.315047
Ed.4	1.09		.140501	0.95		.174974
Ed.5	1.59		.05993	1.44		.078617

$p < .05$ ; Note.  $t = t$ -test statistics;  $df =$  degrees of freedom;  $p = p$ -value.

The results show that there are no significant differences based on the gender variable ( $p < .05$ ) in either the pre-test or the post-test; therefore, the sample will be treated as if it were a single group.

To analyze the change in environmental attitudes in students, the t-test for related samples was performed between the results of the pre-test and the post-test. In addition, Cohen's  $d$  was obtained. The results are shown in Table 5.

Table 5. t-Test results for paired samples on pre-test and post-test and effect size.

Dimensions	t	df	p	d
<i>Environment</i>	15.12	43	<.00001	2.21
E.1	6.72		<.00001	1.27
E.2	5.99		<.00001	0.69
E.3	6.60		<.00001	0.94
E.4	6.27		<.00001	1.12
E.5	8.26		<.00001	1.26
<i>Economy</i>	7.60		<.00001	1.24
Ec.1	5.99		<.00001	0.90
Ec.2	5.52		<.00001	1.11
Ec.3	6.43		<.00001	1.11
Ec.4	5.04		<.00001	0.90
Ec.5	5.04		<.00001	0.85
<i>Society</i>	7.33		<.00001	0.74
S.1	5.37		<.00001	0.84
S.2	3.33		.00181	0.43
S.3	3.33		.00181	0.41
S.4	3.33		.00181	0.43
S.5	2.35		.02355	0.27
<i>Education</i>	8.32		<.00001	1.19
Ed.1	6.27		<.00001	1.07
Ed.2	3.56		.00093	0.43
Ed.3	2.35		.02355	0.23
Ed.4	5.20		<.00001	0.87
Ed.5	2.35		.02355	0.22
Total	15.54		<.00001	2.34

$p < .05$ ; Note.  $t = t$ -test statistics;  $df =$  degrees of freedom;  $p = p$ -value;  $d =$  Cohen's  $d$ .

The results show a significant difference between the pre-test and the post-test for all items, for each dimension, and for the total. A large effect size is also observed for the

dimensions *Environment* ( $t(43) = 15.12, p < .00001, d = 2.21$ ), *Economy* ( $t(43) = 7.60, p < .00001, d = 1.24$ ), and *Education* ( $t(43) = 8.32, p < .00001, d = 1.19$ ), while for *Society* ( $t(43) = 7.33, p < .00001, d = 0.74$ ) there is a moderate-high effect size. In addition, most items show a large effect size, so those that obtain an effect size smaller than the value considered as the average effect are indicated ( $d = 0.5$ ). These are within the dimensions of *Society* and *Education*: S.2 ( $t(43) = 3.33, p = .00181, d = 0.43$ ), S.3 ( $t(43) = 3.33, p = .00181$ ), S.4 ( $t(43) = 3.33, p = .00181, d = 0.43$ ), S.5 ( $t(43) = 2.35, p = .02355, d = 0.27$ ), Ed.2 ( $t(43) = 3.56, p = .00093, d = 0.43$ ), and Ed.5 ( $t(43) = 2.35, p = .02355, d = 0.22$ ).

## 5. Discussion

This research shows the design of a program for the EE subject of preservice teachers that incorporates the four pillars of ESD, environment, economy, society, and education (Ekpiken & Ukpabio, 2015; Biasutti & Frate, 2017), through the SL pedagogy. The planning of the activities was based on the Theory of Experiential Learning (Hung et al., 2023; Kolb, 1984; Kolb et al., 2000; Narong & Hallinger, 2023), used as a pedagogical framework in the design of learning environments in scientific disciplines (Lehane, 2020) and in the field of EE (Diez-Ojeda et al., 2024a, 2024b; Moseley et al., 2020).

The assessment of the developed SL projects obtains favorable ratings in the evaluation rubric (Rubio-Serrano et al., 2015). This ensures that the SL project has a correct definition, planning, and structure in the areas of service, learning, and sustainability. Thus, it facilitates the learning and development of skills of preservice teachers, involves different external agents (educational center, associations), and has an orientation towards community benefit, in particular towards children's learning in SD aspects. It also includes project evaluation mechanisms and moments dedicated to reflection, both by the preservice teachers during the development of the activities and by the children who receive the benefits (Furco, 1996; O'Connor, 2012; Olberding & Hacker, 2015; Queiruga-Dios et al., 2021; Rubio-Serrano et al., 2015; Salam et al., 2019).

Regarding ASD, the initial scores can be considered high, since they are above the average score of the scale, and are slightly higher than those found in other studies on preservice teachers (Nousheen et al., 2020), and similar to those found by Biasutti and Frate (2017) in their study conducted by undergraduate students of different degrees (agriculture, engineering, primary education, and psychology). These pretest scores are especially high in the dimensions *Society* (4.27) and *Education* (4.11). After the educational intervention, the mean scores in each of the dimensions rise significantly, being, in this case, *Environment* (3.97), *Economy* (4.26), *Society* (4.51), and *Education* (4.38). Thus, preservice teachers have scored higher in the *Society* and *Education* dimensions compared to *Environment* and *Economy*. This is in line with the study by Biasutti and Frate (2017), which explains the small differences in the mean scores of the dimensions based on the degree that the students are in. For example, psychology students obtained higher scores in the *Social* dimension. However, in the study by Nousheen et al. (2020), after the educational intervention, the preservice teachers obtained the highest score in the dimension of *Environment* (4.43), which could be due to the duration of the course, in this case sixteen weeks, while the development of the entire SL project took a total of five two-hour sessions. This fact, together with the significant changes in environmental attitudes in all items in the project participants, confirms that SL is a pathway to ESD and thus contributes to the achievement the SDGs. This fact is relevant considering the interest of universities in integrating the SDGs (Alcántara-Rubio et al., 2022; Martín Bautista-Cerro et al., 2023) and the few initiatives in higher education that integrate ESD or the education approach for the SDGs into the curriculum (Geng & Zhao, 2020). Thus, the SL is presented as a way to advance SDGs from the EE. Moreover, the large effect sizes obtained also confirm the success of the intervention carried out with

the preservice teachers in improving ASD. This analysis shows that the largest effect size is observed for the dimension *Environment* ( $t(43) = 15.12, p < .00001, d = 2.21$ ).

In summary, participation in the SL project has allowed future teachers to achieve the academic learning proposed in the course program, such as knowledge of basic aspects of ecology and the environment, analysis of the causes and consequences of environmental problems, research into environmental problems, and the design of educational environmental projects. Furthermore, the development of the SL project, through the sequence of activities, has favored the development of the proposed competences (Diez-Ojeda et al., 2024a, 2024b). In this way, the preservice teachers have been able to identify the main environmental problems of today, and to conceptualize the environment as a set of systems and interactions that make life on the planet possible (Steele, 2010), based on the activities carried out. Also, participation in the project has favored the students' ability to transmit ideas and knowledge to a non-specialized audience, to solve problems, and to ask questions, all of which are academic objectives of the subject. The community has also benefited from the SL project, with an exchange of knowledge and reflections between educational centers and the university, and the improvement of the skills of the agents involved, generating synergies that will give continuity to the project. Finally, the children of primary education level who have participated in the activity have received environmental training that has allowed them to understand some of the environmental problems and how they affect the entire planet, and, at the same time, encouraged them to make a commitment and take action by drawing up and signing of a manifesto.

## 6. Conclusions

This research addresses the scarcity of scientific studies on the impact of future teachers' participation in SL projects within the SDG framework on improving their ASD. Likewise, the study presents methodological keys to integrate these initiatives into the EE subject curriculum, proposing a basis for a possible framework aligned with ESD. SL activities developed from higher education represent a significant advance towards the SDGs. Furthermore, given that these objectives are interrelated, the design of SL initiatives allows us to comprehensively and flexibly address global challenges from multiple perspectives, aligning higher education with the commitment to sustainability. In this sense, the greatest finding of this research refers to the academic benefits of incorporating SL pedagogy, contextualized in the SDGs, for the promotion of ESD and for the improvement of all ASD dimensions: *Environment, Economy, Society, and Education*.

This study has significant implications for educational policies. In this sense, the authors recommend educational authorities to create institutional frameworks that facilitate the incorporation of SL activities and projects into university educational programs, beyond the EE subject. This would allow the educational advantages that SL pedagogy brings to students, researchers (e.g., improving self-efficacy, self-esteem, motivation towards learning, and skills), and the institution itself (e.g., strengthening the institution's image and increasing student retention) to be integrated into university structures, in turn strengthening ties with society. At the same time, this would be a way to respond to the needs of universities to adhere to the SDGs that would generate an impact on the institution itself, its teachers, and its students, and would also generate an impact on the social environment of the university.

Although the case study presented in this research is a very specific experience of incorporating SL in higher education in the training of preservice teachers, this pedagogy can be incorporated into all university studies and degrees in each of the subjects in real-world contexts, orienting learning towards community service and reflection. To do so, a prior study of the university context is necessary to detect the needs of the communities.

On the other hand, increasing digitalization and increasingly rapid access to large volumes of information allow the concept of community to be expanded, favoring the development of SL projects anywhere on the planet from any location.

This study has some limitations. First, the small sample size of students suggests the need to replicate the study with larger samples and in diverse contexts to obtain more generalizable results. Despite this limitation, the study provides a starting point for future studies exploring the change in ASD in future teachers after participation in SL projects. Furthermore, the specific context of our university limits the generalization of the results to other institutions and countries, so it is advisable to carry out similar research in different academic environments to contrast the findings. Nevertheless, these results may be of interest to researchers and teachers in other contexts, providing an initial basis for future research and experiences in the field of ESD.

As for future lines of research, it is proposed to increase the sample size of teachers in training and design longer SL programs, including field activities, and analyze how this impacts changes in ASD.

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## 5. Conclusiones generales

Los estudios llevados a cabo en esta tesis doctoral abordan la escasez existente en la literatura científica relativas a la incorporación de enfoques metodológicos activos orientados a la acción ambiental y social, como la ciencia ciudadana y el Aprendizaje y servicio, en la Educación Ambiental para la formación del profesorado. La incorporación de estos enfoques mejora significativamente las actitudes ambientales y las actitudes hacia el desarrollo sostenible de las personas participantes. Así pues, estos enfoques pedagógicos pueden resultar en un factor clave que permita la reinención y actualización de la educación ambiental a partir del análisis de cuestiones ambientales y sociales específicas que afectan a la comunidad local y a distintas comunidades locales, de forma que permitan a las personas participantes adquirir el conocimiento de los problemas ambientales como una cuestión global. Esto resulta especialmente relevante en la formación del profesorado, debido al papel crítico que desempeñarán los futuros maestros de hoy, ya que serán responsables de la educación de una proporción significativa de jóvenes en el futuro. El profesorado juega un papel clave en la Educación Ambiental efectiva en el aula y puede influir en las visiones del mundo y actitudes del alumnado desde las edades tempranas, sus interacciones con el medio ambiente, su participación en la toma de decisiones y su capacidad para tomar decisiones informadas y responsables. Si el profesorado (o futuro profesorado) carece de conocimientos, habilidades o compromiso, es poco probable que tenga éxito como líder del cambio ambiental en las escuelas y en la generación de estudiantes alfabetizados en materia ambiental. Por otro lado, el desarrollo de estos enfoques desde las instituciones de educación superior y universidades supone una orientación de la educación hacia los ODS, aportando una educación de calidad. Así pues, teniendo en cuenta que los ODS están interrelacionados, el diseño de estas iniciativas permite abordar de forma integral y flexible los retos globales desde múltiples perspectivas, alineando la educación superior con el compromiso de la Educación para el Desarrollo Sostenible.

Además, en los estudios que forman parte de esta tesis doctoral se incorporan las claves metodológicas para la integración de estos enfoques en el currículo de la asignatura de Educación Ambiental para la formación del profesorado, lo que podría ser el origen de un marco de trabajo para el desarrollo curricular de la Educación Ambiental.

## 6. Implicaciones educativas

Algunas de las implicaciones educativas de los estudios realizados en esta tesis se refieren al futuro profesorado ya que debe prestarse especial atención al papel crítico que desempeñará el futuro profesorado de hoy, que será responsable de la educación de una proporción significativa de jóvenes en el futuro. Si el profesorado, como modelo a seguir, es consciente de la necesidad de cuidar el medio ambiente, su alumnado también lo será. Según esta investigación, es crucial que el futuro profesorado refleje en su comportamiento lo que enseña en las clases de Educación Ambiental. Por ello, debe formarse como líder de educación ambiental y promover la idea de que la naturaleza no necesita a las personas, las personas necesitan a la naturaleza. Para una comprensión más profunda, los proyectos a desarrollar pueden incluir diversas actividades que ayuden a los futuros docentes a encontrar soluciones para reducir la contaminación ambiental.

Estos estudios también tienen implicaciones de relevancia para las políticas educativas. En este sentido, la autora recomienda a las autoridades educativas crear marcos institucionales que faciliten la incorporación de actividades y proyectos como los descritos en esta Tesis Doctoral en los programas educativos universitarios, más allá de la asignatura de Educación Ambiental. Esto permitiría integrar en las estructuras universitarias las ventajas educativas que las pedagogías descritas aportan al alumnado, a las personas que se dedican a la investigación (como mejora de la autoeficacia, autoestima, motivación hacia el aprendizaje y competencias) y a la propia institución (como fortalecimiento de la imagen de la institución y el aumento de la retención de los estudiantes), fortaleciendo a su vez los vínculos con la sociedad. Al mismo tiempo, esta sería una forma de dar respuesta a las necesidades de las Universidades de adherirse a los ODS que generaría un impacto en la propia institución, en sus docentes y estudiantes, y también generaría un impacto en el entorno social de la Universidad. Así, aunque los casos de estudio presentados en esta investigación representan una experiencia muy concreta de incorporación de estos enfoques pedagógicos en la educación superior en la formación de futuros docentes, esta pedagogía puede incorporarse a todos los estudios y titulaciones universitarias en cada una de las asignaturas a través de contextos del mundo real, orientando el aprendizaje hacia el ambiente, el servicio comunitario y la reflexión. Para ello, es necesario un estudio previo del contexto universitario para detectar las necesidades de las comunidades. Por otro lado, la creciente digitalización y el acceso cada vez más rápido a grandes volúmenes de información permiten ampliar el concepto de comunidad, favoreciendo el desarrollo de proyectos en cualquier parte del planeta desde cualquier localización.

## 8. Futuras líneas de investigación

Como futuras líneas de investigación y con el propósito de reforzar los resultados de esta investigación, sería recomendable realizar estudios longitudinales para analizar la calidad de la Educación Ambiental de los docentes participantes en este programa, cuando trabajan con niños en las escuelas, y, también, analizar los resultados de esta educación en los estudiantes más jóvenes. Los estudiantes participantes en esta investigación fue profesorado en formación y la investigación se ha desarrollado en la asignatura de Educación Ambiental. Sin embargo, la autora considera, y esta es también una línea de investigación futura, que debido a la gran cantidad de áreas y temáticas que abarcan los proyectos de ciencia ciudadana o de Aprendizaje y servicio, así como a su carácter práctico y aplicado, pueden incorporarse a muchas otras asignaturas y titulaciones universitarias. Incluso se podría desarrollar un proyecto entre distintas asignaturas y/o distintas titulaciones o distintas universidades de forma que la ciencia ciudadana y el Aprendizaje y servicio se integraran en los planes de estudio, lo que, a su vez podría proporcionar un marco para abordar los ODS.

Otras futuras líneas de investigación se centrarán en estudiar los cambios en los modelos mentales de los futuros docentes a través de su participación en proyectos de ciencia ciudadana y Aprendizaje y servicio, incorporando enfoques interdisciplinarios como STEM y STEAM. Además, en relación con los modelos mentales, cabe señalar que estos sirven como marco cognitivo para comprender las prácticas docentes de los educadores. Es probable que los modelos mentales adecuados que tienen los futuros docentes en relación con el aprendizaje, combinados con modelos adecuados en relación con el medio ambiente, fomenten el desarrollo de modelos ambientales precisos en los estudiantes más jóvenes. Esto abre una nueva vía para la investigación

sobre la relación entre los modelos mentales de aprendizaje de los docentes y la calidad de la educación ambiental proporcionada.

Por último, como futura línea de investigación, se propone aumentar el tamaño muestral de docentes en formación y diseñar programas de formación de mayor extensión temporal, incluyendo actividades de campo, y analizar cómo esto impacta en las diferentes variables de estudio.

## 9. Limitaciones

Este estudio tiene algunas limitaciones. En primer lugar, el pequeño tamaño muestral de estudiantes, debido al muestreo de conveniencia, sugiere la necesidad de replicar los estudios con muestras más amplias y en contextos diversos para obtener resultados más generalizables. A pesar de esta limitación, estos estudios proporcionan un punto de partida para investigaciones futuras. Además, el contexto específico de la Universidad de Burgos limita la generalización de los resultados a otras instituciones y países, por lo que es recomendable realizar investigaciones similares en diferentes entornos académicos para contrastar los hallazgos. No obstante, estos resultados pueden ser de interés para investigadores y docentes en otros contextos, proporcionando una base inicial para futuras investigaciones y experiencias en el ámbito de la Educación Ambiental y la Educación para el Desarrollo Sostenible.





