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PROJECT-BASED LEARNING IN ENVIRONMENTAL EDUCATION IN THE TEACHING PRACTICUM: FORMATIVE EXPERIENCES FOR THE DEVELOPMENT OF SUSTAINABILITY SKILLS

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ABSTRACT

Project-based environmental learning is recognized as a relevant pedagogical strategy for addressing socio-environmental challenges in initial teacher education, particularly within the practicum, a key space for articulating theory and professional practice. The objective of this study was to analyze project-based environmental learning in the teaching practicum as a formative experience for the development of sustainability competencies. The research followed a mixed-methods approach, with a non-experimental, cross-sectional design and a descriptive–correlational scope, involving a sample of 120 pre-service teachers. A validated questionnaire and semi-structured interviews were applied, and the data were analyzed using descriptive and correlational statistics, as well as qualitative thematic analysis. The results showed high levels of contextualization, active participation, and action orientation in environmental projects, along with a high level of development of sustainability competencies, particularly ethical commitment, systemic thinking, and critical reflection. Significant positive relationships were identified between the dimensions of project-based learning and sustainability competencies. It was concluded that project-based environmental learning in the practicum strengthened professional training and teacher identity, constituting an effective strategy for promoting sustainability competencies in initial teacher education.

KEYWORDS: Active Methodologies, Education for Sustainability, Professional Competencies.

1. INTRODUCTION

The contemporary socio-environmental crisis (marked by climate change, biodiversity loss, ecosystem degradation, and widening social inequalities) has positioned sustainability as a priority axis on educational agendas worldwide. In this context, Education for Sustainable Development (ESD) has become a guiding framework that goes beyond the mere acquisition of environmental knowledge, fostering the development of critical, ethical, and practical competencies oriented toward the transformation of social reality (Saari et al., 2024). Within this scenario, initial teacher education assumes a strategic role, as future teachers act as multiplying agents of values and practices related to sustainability.

Various international organizations emphasize that the effective integration of sustainability into education depends largely on teachers' capacity to design meaningful, contextualized, and action-oriented learning experiences (Nousheen et al., 2024). However, the literature highlights the persistence of gaps between the normative proposals of ESD and their actual implementation in teacher education processes, particularly within the practicum, a space in which students are expected to articulate theory and practice in authentic educational contexts (Heras et al., 2023).

Against this backdrop, project-based learning (PBL) has emerged as an active methodology with high potential for addressing complex environmental issues through interdisciplinary, participatory, and problem-solving approaches. PBL fosters students' active engagement in processes of inquiry, design, and project implementation, promoting the development of cognitive, socio-emotional, and professional competencies aligned with sustainability (Martínez et al., 2023). In teacher education, this methodology has been associated with improvements in autonomy, critical reflection, and the transfer of learning to real school contexts (Tsybulsky & Muchnik, 2021).

Recent empirical evidence confirms that the use of PBL in initial teacher education programs contributes to strengthening key sustainability competencies, such as systems thinking, ethical decision-making, collaboration, and socio-environmental responsibility (Koçulu, 2025; Paristiowati et al., 2022). Furthermore, environmentally focused projects have been shown to facilitate understanding of the Sustainable Development Goals and to foster a proactive attitude toward transformative action among future teachers (Aramburuzabala & Cerrillo, 2023; Karvonen, 2025).

Nevertheless, despite a growing body of studies on PBL and related methodologies (such as service-learning or community action projects) much of this research focuses on theoretical courses or extracurricular experiences, relegating the specific analysis of the practicum as a key space for the construction of professional sustainability competencies (Partoune et al., 2022; Simon, 2024). This limitation is particularly relevant given that the practicum constitutes the formative moment in which future teachers directly confront the complexity of the school context.

From a theoretical perspective, the practicum is conceived as a situated learning scenario that promotes reflection in and on action, enabling the integration of disciplinary, pedagogical, and contextual knowledge (Tsybulsky & Muchnik, 2021). When this space is articulated with environmental PBL, favorable conditions are created for the design and implementation of contextualized educational proposals oriented toward concrete socio-environmental issues and the needs of educational communities (Salvadó & Novo, 2025). However, the literature warns that the absence of systematized models and clear analytical frameworks limits understanding of the formative scope of these experiences (Stouthart et al., 2023).

Several studies concur that future teachers display positive attitudes toward sustainability but exhibit weaknesses in applied knowledge, instructional design, and the assessment of ESD-related learning outcomes, particularly when professional practice does not incorporate active methodologies (Christodoulou & Papanikolau, 2023; Nousheen et al., 2024). Added to this is the limited problematization of the role of mentoring and institutional support in the implementation of environmental projects during the practicum, despite their influence on the consolidation of sustainability competencies (Palavan et al., 2025).

In this context, a knowledge gap is identified regarding the need to comprehensively understand how project-based environmental learning, implemented specifically within the teaching practicum, contributes to the development of sustainability competencies from a formative and experiential perspective. Although there are studies on PBL, ESD, and teacher education, research that integrates these three axes within a single analytical framework (considering lived experiences, processes of pedagogical reflection, and professional learning derived from practice in real contexts) remains limited (Heras et al., 2023; Karvonen, 2025).

From this perspective, the overall objective of the

study is to analyze project-based environmental learning in the teaching practicum as a formative experience for the development of sustainability competencies. Specifically, the study aims to describe the characteristics of environmental PBL experiences developed during the practicum, identify the sustainability competencies fostered in future teachers, and analyze the formative perceptions associated with the implementation of these projects. The study seeks to provide systematized evidence to enhance understanding of the pedagogical value of environmental PBL within the practicum and to inform improvements in teacher education programs from a perspective committed to sustainability and educational transformation.

2. METHODOLOGY

The research was conducted under a mixed-methods approach, systematically integrating quantitative and qualitative methods to understand the phenomenon under study. The choice of this approach was justified by the need, on the one hand, to analyze the level of development of sustainability competencies through standardized measurements and, on the other, to gain deeper insight into the formative experiences and perceptions of pre-service teachers during the practicum through qualitative information (Hernández et al., 2014). This approach enabled a more comprehensive understanding of the object of study, overcoming the limitations of exclusively quantitative or qualitative approaches.

From Bisquerra's (2009) perspective, contemporary educational research requires integrative approaches that make it possible to understand complex and contextualized processes, such as those that occur in teacher education. In this sense, the mixed-methods approach facilitated data triangulation and strengthened the internal validity of the results.

Furthermore, the study was classified as applied research, as it aimed to generate knowledge with practical utility for improving initial teacher education processes, specifically in the field of the practicum and education for sustainability. The design adopted was non-experimental, since no independent variable was deliberately manipulated; rather, phenomena were observed and analyzed as they occurred in their natural context (Hernández et al., 2014).

Likewise, a cross-sectional design was employed, given that data collection was carried out at a single point in time, after the completion of the project-based environmental learning experiences developed during the teaching practicum period. This design made it possible to obtain a diagnostic snapshot of the development of sustainability competencies and the formative perceptions associated with these experiences.

Regarding its scope, the research had a descriptive–correlational character. It was descriptive because it allowed for the characterization of project-based environmental learning experiences implemented in the teaching practicum and the level of development of sustainability competencies among participants. At the same time, it was correlational, as it analyzed the relationships between the dimensions of project-based environmental learning and the sustainability competencies developed by future teachers, without seeking to establish direct causal relationships (Bisquerra, 2009).

This level of research was appropriate given that the central objective of the study was to understand and analyze an emerging educational phenomenon for which empirical evidence is still limited and fragmented, particularly in the context of the teaching practicum.

2.1. Participants

The population consisted of students in initial teacher education who were undertaking the practicum in university education programs. These students were actively participating in basic and secondary educational institutions, where they developed pedagogical projects with an environmental focus as part of their professional practice activities.

The sample was non-probabilistic and purposive, selected based on specific criteria related to the objectives of the study. It consisted of 120 pre-service teachers who participated voluntarily in the research and met the established inclusion criteria. Below is the general characterization of the sample:

Table 1: Research sample.

Characteristic	Category	Frequency	Percentage
Sex	Female	72	60%
	Male	48	40%
Age	20–24 years	65	54.2%
	25–29 years	40	33.3%
	30 years or older	15	12.5%
Level of practicum	Basic education	70	58.3%
	Secondary education	50	41.7%

The selection of the sample was justified by its relevance for the analysis of the phenomenon under study, given that the participants were at a key stage of their professional training, in which the articulation between theory and practice is essential

for the development of teaching competencies.

The inclusion criteria considered were as follows: students enrolled in initial teacher education programs; active participation in the practicum during the academic period of the study; implementation of or participation in educational projects with an environmental focus; voluntary agreement to participate in the research through informed consent. The exclusion criteria included the following: students who did not carry out activities related to environmental projects during the practicum; participants who did not complete all data collection instruments; and pre-service teachers who were engaged in administrative or non-pedagogical placements.

2.2. Procedure

The research procedure was developed in four clearly differentiated phases, which enabled an orderly and coherent execution of the study.

Phase 1: Planning and instrument design. In this phase, an exhaustive review of the scientific literature on project-based learning, education for sustainability, and teacher education was conducted, allowing for the definition of the dimensions of analysis and the design of the data collection instruments. Two main instruments were developed: a structured questionnaire and a semi-structured interview guide.

Phase 2: Instrument validation. The questionnaire underwent a content validity process through expert judgment, involving five academics with experience in environmental education, active methodologies, and teacher education. The suggestions provided helped improve the clarity, relevance, and coherence of the items. Subsequently, a pilot test was conducted with 25 students with characteristics similar to those of the final sample. Based on these data, the reliability of the instrument was calculated using Cronbach's alpha coefficient, obtaining a value of 0.87, considered adequate according to the criteria established by Hernández et al. (2014). The interview guide was validated through peer review by academic colleagues, ensuring alignment between the questions and the qualitative objectives of the study.

Phase 3: Data collection. Data collection was carried out after the completion of the practicum period. The questionnaire was administered both in person and online, ensuring the confidentiality and anonymity of participants. In parallel, semi-structured interviews were conducted with a purposive subsample of 20 participants, in order to gain deeper insight into their formative experiences.

Phase 4: Organization and systematization of information. Quantitative data were coded and entered into a database, while the interviews were transcribed verbatim for subsequent qualitative analysis. This process ensured the fidelity of the information and facilitated its analytical treatment.

2.3. Data Analysis

In the quantitative analysis, descriptive statistical techniques were employed, such as frequencies, percentages, means, and standard deviations, in order to characterize the sustainability competencies developed by the participants. Subsequently, correlational analyses were performed using Spearman's correlation coefficient, considering the ordinal nature of the data, to identify relationships between the dimensions of project-based environmental learning and sustainability competencies.

The qualitative analysis of the interviews was carried out through a thematic coding process, following an inductive approach. Categories and subcategories related to formative experiences, significant learning outcomes, and perceived difficulties during the implementation of environmental projects in the practicum were identified. This analysis made it possible to complement and interpret the quantitative results, fostering a deeper understanding of the phenomenon under study.

Finally, a data triangulation process was conducted, integrating quantitative and qualitative findings to strengthen the validity of the results and to offer a comprehensive view of the impact of project-based environmental learning on the development of sustainability competencies in initial teacher education (Bisquerra, 2009; Hernández et al., 2014).

3. RESULTS

This section systematically presents the results obtained from the quantitative and qualitative analysis of the collected data, in direct coherence with the objectives established in the study and the methodological procedure described. The results are organized according to the specific objectives: (a) to describe the characteristics of project-based environmental learning (PBL) experiences developed during the teaching practicum; (b) to identify the level of development of sustainability competencies among pre-service teachers; and (c) to analyze the relationship between environmental PBL experiences and the development of these competencies, as well as the associated formative

perceptions.

3.1. Characteristics of Project-Based Environmental Learning Experiences in the Practicum

The descriptive results show that the environmental PBL experiences developed during the practicum exhibit a high degree of pedagogical structuring and contextualization. Most participants design projects linked to local environmental issues, such as waste management, water conservation, urban biodiversity, and climate education, integrating curricular content from various subject areas. Table 2 presents the distribution of the main methodological characteristics of the environmental projects implemented.

Table 2: Characteristics Of Environmental Projects Developed in the Teaching Practicum.

PBL characteristic	Low level (%)	Medium level (%)	High level (%)
Contextualization of the environmental problem	8.3	27.5	64.2
Interdisciplinarity	12.5	35.8	51.7
Active student participation	6.7	30.0	63.3
Collaborative work	5.8	28.4	65.8
Action- and solution-oriented approach	10.0	33.3	56.7

The data indicate that more than 60% of pre-service teachers implement projects with a high level of contextualization and active participation, reflecting a solid appropriation of PBL principles. Action orientation, understood as the generation of concrete proposals to address environmental issues, reaches high levels in more than half of the cases, which is consistent with the formative objectives of education for sustainability.

3.2. Level Of Development of Sustainability Competencies

Regarding the second objective, the results of the descriptive analysis show that pre-service teachers achieve predominantly medium and high levels in the assessed sustainability competencies. These competencies are grouped into four dimensions: systems thinking, ethical and social commitment, pedagogical action for sustainability, and critical reflection. Table 3 presents the descriptive statistics corresponding to each dimension.

Table 3: Level of development of sustainability competencies.

Dimension	Mean	Standard deviation	Predominant level
Systems thinking	4.12	0.58	High
Ethical and social commitment	4.25	0.54	High
Pedagogical action for sustainability	3.98	0.63	Medium–High
Critical reflection	4.05	0.60	High

The results show that ethical and social commitment presents the highest mean, indicating that participants display high sensitivity to socio-environmental issues and recognize their role as future teachers in promoting sustainability values. Systems thinking also reaches high values, reflecting pre-service teachers' ability to understand the interrelationships among environmental, social, and educational factors.

The dimension of pedagogical action for sustainability, although situated at a medium–high level, shows slightly greater dispersion, suggesting differences in participants' ability to translate their knowledge and attitudes into concrete instructional strategies during teaching practice.

3.3. Relationship between project-based environmental learning and sustainability competencies

To address the third objective, a correlational analysis was conducted between the dimensions of environmental PBL and sustainability competencies, using Spearman's correlation coefficient. The results are presented in Table 4.

Table 4: Correlations Between Environmental PBL Dimensions and Sustainability Competencies.

PBL dimensions	Systems thinking	Ethical commitment	Pedagogical action	Critical reflection
Project contextualization	0.61**	0.58**	0.55**	0.60**
Collaborative work	0.57**	0.62**	0.59**	0.56**
Active participation	0.63**	0.60**	0.65**	0.61**
Action orientation	0.59**	0.64**	0.68**	0.62**

The results show positive and statistically significant correlations between all dimensions of environmental PBL and sustainability competencies. Active student participation and action orientation present the highest correlations with pedagogical action for sustainability, indicating that projects that actively engage students and promote concrete solutions foster the development of didactic

competencies oriented toward sustainability.

Likewise, project contextualization is significantly associated with systems thinking and critical reflection, demonstrating that addressing real environmental issues contributes to a deeper and more complex understanding of socio-environmental challenges.

3.4. Qualitative Results: Formative Perceptions of Environmental PBL in the Practicum

The qualitative analysis of the interviews allowed for the identification of emerging categories that complement and deepen the quantitative results. The main categories identified were: meaningful learning, development of teacher identity, socio-environmental awareness, and challenges in implementation.

Regarding meaningful learning, participants report that environmental PBL enables them to link theoretical content with real-life situations, thereby strengthening understanding and motivation. Pre-service teachers emphasize that working with concrete environmental problems promotes more lasting and relevant learning.

The category development of teacher identity reveals that the implementation of environmental projects during the practicum contributes to future teachers perceiving themselves as agents of change. Participants indicate that these experiences strengthen their professional confidence and their ability to design innovative pedagogical proposals.

With respect to socio-environmental awareness, qualitative results show that environmental PBL promotes a more critical and committed perspective toward environmental issues. Pre-service teachers recognize the importance of incorporating sustainability transversally into their future practice.

Finally, the category challenges in implementation highlights difficulties related to available time, institutional support, and coordination with mentor teachers. However, these challenges do not limit the formative value of the experiences; rather, they constitute opportunities for professional learning.

Integration of quantitative and qualitative results

The triangulation of quantitative and qualitative results makes it possible to affirm that project-based environmental learning in the teaching practicum is consistently associated with the development of sustainability competencies. Quantitative data show high levels of these competencies and significant relationships with PBL dimensions, while qualitative findings provide a deeper understanding of the underlying formative processes.

Overall, the results confirm that the practicum, when articulated with active methodologies such as environmental PBL, becomes a privileged formative space for the construction of professional competencies oriented toward sustainability. These findings directly address the objectives established in the study and lay the groundwork for the discussion and interpretation of the results in the following section.

4. DISCUSSION

The results of this study allow for a consistent interpretation of project-based environmental learning in the teaching practicum as a relevant formative strategy for the development of sustainability competencies. The findings confirm that the systematic incorporation of contextualized, participatory, and action-oriented environmental projects fosters not only knowledge acquisition but also the consolidation of attitudes, values, and professional skills aligned with the principles of Education for Sustainable Development, in agreement with recent literature (Karvonen, 2025; Saari et al., 2024).

Regarding the first objective, the results show that environmental PBL experiences developed during the practicum exhibit high levels of contextualization, active participation, and collaborative work. These findings are consistent with Tsybulsky and Muchnik (2021), who emphasize that projects situated in real contexts strengthen the integration of theory and practice, promoting meaningful learning. Similarly, Martínez et al. (2023) argue that contextualizing projects around concrete socio-environmental issues increases pedagogical relevance and interdisciplinarity, aspects clearly reflected in the findings of the present study.

The high level of active student participation and action orientation observed reinforces the value of project-based learning as an appropriate methodology for sustainability education. In this regard, Paristiowati et al. (2022) note that PBL positions pre-service teachers as protagonists of the learning process, fostering greater cognitive and emotional engagement. This engagement is reflected in the results obtained, particularly in participants' ability to design pedagogical proposals aimed at addressing environmental problems, in line with Aramburuzabala and Cerrillo (2023), who highlight the transformative potential of action-oriented active methodologies linked to community engagement.

With respect to the second objective, the results show predominantly high levels of sustainability

competencies, especially in ethical and social commitment, systems thinking, and critical reflection. This finding aligns with Nousheen et al. (2024), who assert that formative experiences that explicitly integrate sustainability strengthen the ethical awareness of future teachers. Similarly, Saari et al. (2024) argue that sustainability-oriented initial teacher education broadens understanding of the professional role of teachers as agents of social change.

The high level of systems thinking observed is related to Christodoulou and Papanikolau (2023), who indicate that active methodologies centered on ESD promote the development of complex cognitive skills necessary to address multidimensional socio-environmental problems. Likewise, Koçulu (2025) notes that participation in sustainability projects during initial teacher education strengthens critical analysis and informed decision-making, aspects clearly reflected in the results obtained.

However, the greater variability observed in the dimension of pedagogical action for sustainability indicates that, although pre-service teachers display favorable attitudes and knowledge, differences persist in their ability to translate these elements into concrete instructional practices. This result is consistent with Nousheen et al. (2024) and Stouthart et al. (2023), who identify gaps between conceptual understanding of sustainability and its effective classroom implementation, reinforcing the need to strengthen pedagogical support during the practicum.

Regarding the third objective, correlational analyses reveal positive and significant associations between the dimensions of project-based environmental learning and sustainability competencies. These results confirm that active participation, collaborative work, and action orientation are closely linked to the development of professional competencies, in coherence with Ribeiro et al. (2023) on the formative impact of project-based and service-learning approaches.

The significant relationship between action orientation and pedagogical action for sustainability reinforces Simon's (2024) assertion that action projects allow sustainability to be experienced as a concrete pedagogical practice. Likewise, Salvadó and Novo (2025) show that contextualized environmental projects facilitate the transfer of learning to teaching practice, an aspect confirmed by the results of this study.

From a qualitative perspective, participants' formative perceptions complement and interpret the quantitative findings. Meaningful learning emerges as a central axis, consistent with Partoune et al. (2022), who emphasize that practice-based experiences with an environmental focus promote the internalization of sustainability-related values and knowledge. Similarly, the strengthening of teacher identity as an agent of change aligns with Palavan et al. (2025), who highlight the role of mentoring in consolidating a professional identity committed to sustainability.

The socio-environmental awareness expressed by participants is consistent with Djam'an (2025), who argues that integrating environmental approaches into teacher education fosters a critical understanding of global and local issues. Finally, the challenges identified in implementing environmental projects (such as time constraints and limited institutional support) are consistent with previous studies (Heras et al., 2023; Uyen et al., 2023), without undermining the formative value of PBL. Instead, these challenges consolidate PBL as an opportunity for professional learning, as proposed by Karvonen (2025).

In summary, the results expand existing knowledge by positioning the practicum as a key space for the development of sustainability competencies through project-based environmental learning, providing empirical evidence that addresses gaps identified in the literature and reaffirming the value of PBL as an effective formative strategy in initial teacher education.

5. CONCLUSIONS

Three key highlights of this research corresponded to: environmental PBL in the practicum fostering meaningful learning through real contexts, collaboration, and action-oriented teaching; pre-service teachers strengthening ethical awareness, systems thinking, and critical reflection as core sustainability competencies; and active participation and action-based projects being strongly linked to the development of pedagogical skills for sustainability.

The present study made it possible to systematically analyze project-based environmental learning developed within the teaching practicum as a formative experience oriented toward the development of sustainability competencies, thereby fulfilling the general and specific objectives established. Based on the results obtained, it was concluded that integrating project-based learning with an environmental focus into professional teaching practice constitutes a relevant and effective pedagogical strategy for strengthening initial teacher education from a sustainability-oriented perspective.

With regard to the first objective, it was concluded that the project-based environmental learning experiences implemented during the practicum were characterized by high levels of contextualization, active participation, collaborative work, and interdisciplinarity. These characteristics enabled pre-service teachers to connect curricular content with real environmental issues in their educational contexts, fostering situated and meaningful learning processes. Empirical evidence showed that the practicum, when articulated with active methodologies, ceased to be a merely applicative space and became a setting for pedagogical innovation and professional reflection.

Regarding the second objective, it was concluded that pre-service teachers achieved predominantly high levels in the assessed sustainability competencies, particularly in the dimensions of ethical and social commitment, systems thinking, and critical reflection. These results indicated that participation in environmental projects during teaching practice contributed to the development of a solid socio-environmental awareness and to an understanding of the teaching profession as an agent of change. Nevertheless, greater variability was identified in the dimension related to pedagogical action for sustainability, highlighting the need to further strengthen the translation of sustainability principles into concrete instructional practices.

Concerning the third objective, it was concluded that positive and statistically significant relationships existed between the dimensions of project-based environmental learning and sustainability competencies. These findings confirmed that active student participation, action orientation, and collaborative work were directly associated with the development of pedagogical competencies oriented toward sustainability. The triangulation of quantitative and qualitative results made it possible to affirm that these relationships were not only evident at a declarative level but were also reflected in the formative perceptions and lived experiences of pre-service teachers during the practicum.

From a theoretical perspective, the study contributed to the field of initial teacher education by providing empirical evidence that reinforces the value of project-based environmental learning as a methodology consistent with the principles of Education for Sustainable Development. Furthermore, the study advanced understanding of the practicum as a key formative device for integrating sustainability into teachers' professional identity, addressing a gap identified in the literature, where this space had often been treated in a fragmented or secondary manner.

At a practical level, the conclusions suggest that the systematic incorporation of project-based environmental learning into practicum programs fosters the development of professional competencies that are relevant for addressing contemporary socio-environmental challenges. In this regard, the results offer useful guidance for higher education institutions, teacher educators, and educational policymakers interested in strengthening the environmental dimension of initial teacher education through active and contextualized methodologies.

Finally, the study highlights the need for continued research in this field through longitudinal designs that allow for the analysis of the evolution of sustainability competencies throughout teacher education and their transfer to professional practice after graduation. It also suggests further exploration of the role of mentoring, institutional support, and contextual conditions that facilitate or constrain the implementation of project-based environmental learning in the practicum. In this way, future research can expand and consolidate the knowledge generated, contributing to the design of more comprehensive and sustainable models for teacher education.

REFERENCES

Aramburuzabala, P., & Cerrillo, R. (2023). Service-Learning as an Approach to Educating for Sustainable Development. Sustainability, 15(14). https://doi.org/10.3390/su151411231

Bisquerra, R. (2009). Metodología de la investigación educativa. La Muralla.

Christodoulou, P., & Papanikolaou, A. (2023). Examining Pre-Service Teachers' Critical Thinking Competences within the Framework of Education for Sustainable Development: A Qualitative Analysis. Education Sciences, 13(12). https://doi.org/10.3390/educsci13121187

Djam'an, N. (2025). Examining the implementation of environmental education in the STEAM approach for sustainability. Discover Education, 4. https://doi.org/10.1007/s44217-025-00837-4

Heras, R., Masgrau, M., Guiu, E., Soler, P., & Albertín, P. (2023). Service learning for sustainability in the practicum phase of initial teacher training. Profesorado, Revista De Currículum Y Formación Del Profesorado, 27(1). https://doi.org/10.30827/profesorado.v27i1.21466

Hernández, R., Fernández, C., & Baptista, P. (2014). Metodología de la investigación (6.ª ed.). McGraw-Hill.

Karvonen, R. (2025). Rethinking transformations in sustainability education: project-based approach to sustainability for primary school student teachers. International Journal of Sustainability in Higher Education, 5(2). https://doi.org/10.1108/IJSHE-03-2025-0204

Koçulu, A. (2025). Preparing Future Science Teachers to Build a Sustainable World: Supporting Pre-Service Science Teachers' Competencies in Instructional Planning for Teaching the Sustainable Development Goals (SDGs) in K-12 Classrooms. Sustainability, 17(22). https://doi.org/10.3390/su172210427

Martínez E, Pegalajar, M., & Burgos, A. (2023). Active methodologies and curricular sustainability in teacher training. International Journal of Sustainability in Higher Education, 24(6). https://doi.org/10.1108/IJSHE-05-2022-0168

Nousheen, A., Zia, M., & Waseem, M. (2024). Exploring pre-service teachers' self-efficacy, content knowledge, and pedagogical knowledge concerning education for sustainable development. Environmental Education Research, 30(3). https://doi.org/10.1080/13504622.2022.2128055

Palavan, Ö., Kirikkaleli, N. O., & Güneyli, A. (2025). Mentor Teachers' Opinions for Sustainable Teacher Education: The Case of Northern Cyprus. Sustainability, 17(11). https://doi.org/10.3390/su17115138

Paristiowati, M., Rahmawati, Y., Fitriani, E., Satrio,J, & Putri, N. (2022). Developing Preservice Chemistry Teachers' Engagement with Sustainability Education through an Online Project-Based Learning Summer Course Program. Sustainability, 14(3). https://doi.org/10.3390/su14031783

Partoune, C., Grodos, A., Bernard, H., & Meunier, G. (2022). A five-month full-time eco-traineeship in pre-service primary school training. Environmental Education Research, 29(8). https://doi.org/10.1080/13504622.2022.2132220

Ribeiro, L., Miranda, F., Themudo, C., Gonçalves, H., Bringle, R., Rosário, P., & Aramburuzabala, P. (2023). Educating for the sustainable development goals through service-learning: University students' perspectives about the competences developed. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1144134

Saari, M., Poulton, R., & Vladimirova, A. (2024). Does sustainability really start with teachers? Reflections on integrating environmental education in pre-service teacher education in Namibia and Finland. The Journal of Environmental Education, 55(6). https://doi.org/10.1080/00958964.2024.2375210

Salvadó, Z., & Novo, M. (2025). Dealing with Urban Biodiversity Through Butterfly Gardens: A Project-Based Learning Proposal for Pre-Service Teachers Training. Sustainability, 17(5). https://doi.org/10.3390/su17052195

Simon, R. (2024). Positioning Field Action Projects as Tools for Sustainable Development (With Special Reference to BSSS, Bhopal). Higher Education for the Future, 11(1). https://doi.org/10.1177/23476311231222681

Stouthart, T., Bayram, D., & Van Der Veen, J. (2023). Capturing Pedagogical Design Capacity of STEM Teacher Candidates: Education for Sustainable Development through Socioscientific Issues. Sustainability, 15(14). https://doi.org/10.3390/su151411055

Tsybulsky, D., & Muchnik, Y. (2021). Project-based learning in science-teacher pedagogical practicum: the role of emotional experiences in building preservice teachers' competencies. Disciplinary and Interdsciplinary Science Education Research, 3(9). https://doi.org/10.1186/s43031-021-00037-8

Uyen, B., Tong, D, & Ngan, L. (2023). Online project-based learning for teacher education during the COVID-19 pandemic: A systematic review. Contemporary Educational Technology, 15(3). https://doi.org/10.30935/cedtech/13238