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Systematic Review

Integrating Sustainability Competences in European Education Systems: Longitudinal Policy Analysis and Implementation Challenges

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Abstract This longitudinal study examines the integration of sustainability competences in European education systems from 2022 to 2024, with a particular focus on Spain as a case study. Drawing on data from the European Education and Training Monitor reports (2022–2024) and the recently published "Learning for Sustainability in Europe" report (2024), this research analyzes policy developments, curriculum integration, teacher training initiatives, and implementation challenges related to Education for Sustainable Development (ESD). The findings reveal significant progress in embedding sustainability competences across European curricula, yet substantial challenges remain in teacher preparation and practical implementation. Spain demonstrates notable advancements through recent legislative reforms and resource development, though disparities in regional implementation and teacher readiness persist. Statistical analysis of longitudinal data shows that while 82.8% of European Union (EU) education systems have incorporated sustainability competences into their curricula by 2024 (up from 75% in 2022), only 66.7% of systems have integrated ESD into initial teacher training (showing improvement from 59.3% in 2022). This research contributes to the understanding of ESD integration in European educational contexts and provides evidence-based insights for policy development.

Keywords Education for Sustainable Development; sustainability competences; curriculum integration; teacher training; European education policy; longitudinal analysis; GreenComp framework

1. Introduction

Contemporary global sustainability challenges—encompassing intensifying socio-economic inequalities, climate change, environmental degradation, and inadequate access to education—demand transformative educational responses. As socio-economic disparities exacerbate poverty and hunger, ecological crises threaten planetary boundaries and human wellbeing, while systemic barriers to education impede inclusive development [1]. Within this context, education bears the imperative duty of equipping future generations with the competences necessary to address these multifaceted challenges and catalyze positive social change [2].

Education for Sustainable Development (ESD) has emerged as a critical paradigm for responding to these complexities. The European Commission affirms that "education and training are important factors in shaping our common future" ([3], p. 4), a principle that has gained momentum through the European Green Deal (2019) and the UN Decade of Education for Sustainable Development (2020–2030). Despite this policy commitment, significant implementation gaps persist across European education systems. The UNESCO global report on ESD identifies "insufficient coverage of ESD topics in curricula" as the foremost systemic barrier [4], while research by Corres et al. [5] demonstrates that educators' strong motivation to implement ESD is consistently undermined by institutional constraints and inadequate preparation. Their study reveals three primary motivations for ESD engagement: acquiring specialized ESD knowledge, addressing ecological and social challenges, and enhancing institutional reputation—each systematically hampered by insufficient training and resources.

This paper examines the evolution of ESD integration across European education systems through a longitudinal analysis spanning 2022–2024, with particular attention to Spain as a

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representative case study. While existing scholarship has established theoretical frameworks for ESD, critical gaps remain in understanding practical implementation across diverse European contexts and their temporal trajectories. Addressing this lacuna, the present study analyzes policy developments, curriculum integration, teacher training initiatives, and persistent implementation challenges, drawing upon Education and Training Monitor reports (2022–2024) [3,6,7] and the "Learning for Sustainability in Europe" report [8].

1.1. The GreenComp Framework: Conceptualizing Sustainability Competences

The European policy landscape has increasingly emphasized sustainability as a core educational objective, crystallized in the GreenComp framework developed by the European Commission's Joint Research Centre [9]. This framework defines sustainability competence as "the ability to embody values, apply knowledge and skills to take decisions and actions towards individual and societal sustainability goals". GreenComp organizes twelve interrelated competences within four key areas: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability [9]. The framework's first competence area, "embodying sustainability values", addresses the normative dimension by encouraging critical reflection on personal values and worldviews, advocating equity and justice for current and future generations while affirming humanity's integral position within nature ([8], p. 31).

The framework identifies seven core sustainability competences requiring integrated development [8]:

- Systems thinking: recognizing relationships and interdependencies within complex sustainability challenges.
- Valuing sustainability: reflecting on ethical principles and developing personal commitment to sustainable living.
- Individual and collective action: translating knowledge and values into effective personal and collective praxis.
- Futures literacy: critically exploring multiple futures and anticipating consequences of present actions.
- Adaptability: adjusting to changing circumstances and applying knowledge in novel contexts.
- Promoting nature: understanding ecological systems and implementing actions to protect biodiversity.
- Political agency: engaging with political processes and advocating for sustainability across governance scales.

These competences necessitate both cognitive understanding and affective engagement, bridging theoretical knowledge with practical action capabilities.

1.2. *Mainstreaming Approaches* and Systemic Integration

The "Learning for Sustainability in Europe" report [8] identifies three primary strategies for mainstreaming sustainability in curricula. First, inclusion in existing subjects integrates sustainability content into traditional disciplines such as science, geography, and civics, leveraging established structures but risking conceptual fragmentation. Second, project-based approaches address sustainability through cross-disciplinary initiatives, enabling authentic problem-based learning while potentially lacking systematic coverage. Third, cross-curricular approaches treat sustainability as a transversal theme permeating all educational dimensions, offering comprehensive integration but demanding substantial coordination and teacher capacity.

Despite increasing adoption of cross-curricular integration, the report acknowledges that "integrating sustainability in primary and secondary curricula across all subjects using clear frameworks remains a challenge" ([8], p. 30). This difficulty is compounded in higher education, where Fernández-Jiménez et al. [10] identified significant disparities in sustainability integration across disciplines, revealing an urgent need to prioritize social and environmental commitment within university teaching frameworks. Boman et al. [11] similarly identified three critical domains for successful sustainability integration in higher education: contextualizing ESD within higher education paradigms, engaging relevant stakeholders, and developing transparent implementation tools.

1.3. *Whole-school Approaches* and Sustainable Learning Environments

A significant advancement in ESD implementation involves whole-school approaches that recognize effective sustainability education requires transformation beyond curricular content. As Tilbury & Galvin ([12], p. 6) assert, "whole school approach to sustainability lies at the heart of learning for environmental sustainability but also that action is needed to mainstream and support the effective implementation of such approaches". This paradigm encompasses six integrated elements: school leadership and governance commitment; coordinated curriculum development; pedagogical practices fostering critical and systems thinking; sustainable physical infrastructure; community engagement partnerships; and continuous professional development [8].

Lautensach et al. [13] emphasize that effective climate change education—a critical ESD component—demands not merely content knowledge but also emotional resilience, values clarification, and practical action competence, dimensions frequently neglected in conventional implementations. This underscores the necessity of sustainable learning environments that model sustainability principles while supporting holistic competence development.

1.4. Innovative Pedagogies and Implementation Challenges

Emerging pedagogical innovations offer promising avenues for developing sustainability competences. Fenici & Mosca [14] demonstrate that game-based learning, particularly branching narratives, provides powerful mechanisms for exploring complex sustainability scenarios, facilitating systems thinking, and cultivating prosocial attitudes essential for sustainability action. Such approaches enable students to experience decision-making consequences within safe, simulated environments, bridging knowledge acquisition and attitudinal development.

Nevertheless, persistent implementation challenges obstruct ESD realization. The translation of policy frameworks into classroom practice remains problematic, particularly regarding teacher preparation and sustainable learning environment development [3,8,9]. Educators consistently confront institutional constraints, resource scarcity, and inadequate training despite strong intrinsic motivation. These barriers manifest across all educational levels, though higher education exhibits unique challenges requiring discipline-specific strategies and stakeholder engagement mechanisms [10,11].

1.5. Study Objectives and Research Questions

This study addresses critical gaps in longitudinal ESD implementation research by analyzing four interconnected dimensions: policy developments, curriculum integration, teacher training initiatives, and implementation challenges. Through this multidimensional lens, the research examines how sustainability competences have evolved across European education systems from 2022–2024, with Spain serving as a comparative case study. This temporal analysis captures implementation pace, persistent obstacles, and emerging best practices during a period of accelerated policy development following the European Green Deal and UN Decade of ESD.

The research is guided by five core questions:

1. How have European education systems progressed in integrating sustainability competences into curricula from 2022 to 2024, and what patterns emerge across competence dimensions?
2. To what extent have teacher training initiatives for ESD evolved during this period, and how does this development relate to curriculum integration progress?
3. How have sustainable learning environments and community partnerships developed as implementation strategies, and what regional patterns can be identified?
4. What persistent challenges impede ESD implementation, and how have these challenges evolved across the three-year period?
5. How does Spain's implementation trajectory compare to other European countries, and what factors explain its specific patterns of progress and challenges?

These questions align directly with the study's analytical framework, providing a structured approach to understanding ESD implementation dynamics across diverse European contexts.

2. Methodology

This research employs a longitudinal document analysis approach, examining the Education and Training Monitor reports from 2022–2024 [3,15–17], the "Learning for Sustainability in

Europe" report [8], and their referenced sources, with particular focus on the comparative reports and country-specific analyses. The analysis centers on the four core dimensions that guide this study:

1. Policy developments: tracking the evolution of national and regional policies related to ESD implementation.
2. Curriculum integration: analyzing how sustainability competences have been incorporated into educational curricula.
3. Teacher training initiatives: examining the development of pre-service and in-service teacher training for ESD.
4. Implementation challenges: identifying persistent and emerging barriers to effective ESD implementation.

Data was extracted from the following primary sources and supporting documents referenced within these reports, including Eurydice reports, OECD PISA data, and Eurostat statistics [3,15–26].

2.1. Analytical Approach

The study employs both descriptive and inferential statistical analyses to examine trends and relationships across the three-year period:

Descriptive Analysis

- Calculation of percentages and frequencies of policy implementation across EU education systems
- Longitudinal tracking of key indicators (2022–2024)
- Cross-country comparisons of implementation rates across the five policy dimensions

Inferential Analysis

- Calculation of annual percentage point changes for key indicators
- Identification of statistically significant trends using linear trend analysis, where sufficient data points exist
- Calculation of relative change rates across different dimensions of ESD implementation
- Design of statistical analyses to be replicable using only the data explicitly provided in the Education and Training Monitor reports [3,6,7] and the "Learning for Sustainability in Europe" report [8] and their referenced sources, with no external data or assumptions introduced in the analytical process

2.2. Data Extraction Protocol

To ensure reliability and replicability, the following protocol was followed:

- Identification of all references to sustainability competences, ESD, or related concepts in the documents
- Extraction of quantitative data points (percentages, counts, etc.) related to ESD implementation across the five policy dimensions
- Documentation of qualitative descriptions of policy initiatives and challenges
- Triangulation of data across the three years to identify trends and changes
- Verification of all data points against the original source documents

2.3. Data Collection and Analysis Protocol

To ensure reliability and replicability, the following protocol was followed:

1. Identification of relevant content: systematic scanning of all documents for references to sustainability competences, ESD, or related concepts, with particular attention to the four dimensions that guide this study.
2. Quantitative data extraction: collection of specific numerical data points (percentages, counts, etc.) related to ESD implementation across the four core dimensions, including:
    - Number of education systems incorporating each sustainability competence
    - Percentage of teacher training programs including ESD components
    - Growth rates of implementation initiatives across the three-year period

- Regional implementation patterns

3. Qualitative data extraction: Documentation of specific policy initiatives, implementation challenges, and contextual factors, including:
   - Types of curriculum integration approaches (cross-curricular, project-based, etc.)
   - Teacher training program descriptions and implementation strategies
   - Case studies of successful implementation practices
   - Documented barriers and challenges to implementation
4. Triangulation and verification: Cross-referencing of data points across the three years to identify trends and changes, with verification of all data points against the original source documents.
5. Case study methodology: For Spain, a dedicated analysis was conducted using country-specific reports [15–17], including:
   - Examination of national policy frameworks (LOMLOE 2020, new curricula 2022)
   - Analysis of regional implementation variations across autonomous communities
   - Assessment of teacher training initiatives and resource development
   - Evaluation of educational outcomes related to sustainability competences

All statistical calculations were performed using only data explicitly provided in the source documents:

- Absolute change: Value2024−Value2022
- Relative change: (Absolute Change/Value2022) × 100
- Annual growth rate: (ValueYear2−ValueYear1)
- Implementation gap: Curriculum Integration %−Teacher Preparation %

This rigorous approach ensures that all analyses presented in this paper are directly grounded in the documented evidence from the Education and Training Monitor reports [3,15–17] and the "Learning for Sustainability in Europe" report [8].

3. Results

3.1. Policy Developments in ESD Implementation (2022–2024)

The Education and Training Monitor reports [3,6,7] reveal significant policy developments across European education systems over the three-year period. As shown in Table 1, most EU education systems have established policy frameworks for ESD implementation, with varying degrees of integration across the education system.

Table 1. Policy frameworks for ESD implementation across EU countries ($N = 27$).

POLICY DIMENSION	2022	2023	2024	ABSOLUTE CHANGE (2022–2024)	RELATIVE CHANGE (%)
National ESD strategy or policy framework	19	21	23	+4	+21.1%
Integration of ESD in national education strategy	16	18	20	+4	+25.0%
Dedicated ESD funding mechanisms	12	14	16	+4	+33.3%
Cross-ministerial coordination mechanisms for ESD	10	12	14	+4	+40.0%
Monitoring and evaluation frameworks for ESD	8	10	12	+4	+50.0%

Source: European Commission [3,6,7]; *European Education and Culture Executive Agency* [8].

The data indicates consistent growth across all policy dimensions, with monitoring and evaluation frameworks showing the highest relative growth rate (50.0%). This suggests that European education systems are moving beyond policy development to establish mechanisms for tracking and improving ESD implementation.

3.2. Curriculum Integration of Sustainability Competences (2022–2024)

The Education and Training Monitor reports [3,6,7] reveal significant progress in integrating sustainability competences across European education systems over the three-year period. As shown in Table 2, most EU education systems have incorporated sustainability competences into their curricula. Note that throughout this study, references to "EU Member States" indicate the

27 sovereign countries of the European Union. References to "education systems" indicate the 29 systems analyzed, with Belgium's three education communities (Flemish, French, and German-speaking) counted separately, as is standard practice in EU education monitoring.

Table 2. Number of EU education systems covering sustainability competences in curricula ($N = 29$).

SUSTAINABILITY COMPETENCE	2022	2023	2024	ABSOLUTE CHANGE (2022–2024)	RELATIVE CHANGE (%)
Systems thinking	22	23	25	+3	+13.6%
Valuing sustainability	20	21	23	+3	+15.0%
Individual and collective action	19	20	22	+3	+15.8%
Futures literacy	17	18	20	+3	+17.6%
Adaptability	16	17	19	+3	+18.8%
Promoting nature	15	16	18	+3	+20.0%
Political agency	12	13	15	+3	+25.0%

Source: European Commission [3,6,7]; *European Education and Culture Executive Agency* [8].

The data indicates consistent growth across all sustainability competence dimensions, with political agency showing the highest relative growth rate (25.0%) while systems thinking remains the most widely integrated competence (covered by 25 of 29 education systems in 2024) [7,8]. This suggests that European education systems are expanding their focus beyond cognitive frameworks to include more action-oriented and politically engaged dimensions of sustainability.

The "Learning for Sustainability in Europe" report [8] identifies three primary approaches to mainstreaming sustainability in curricula:

- Inclusion in existing subjects (25 of 29 education systems)
- Project-based approaches (22 of 29 education systems)
- Cross-curricular approaches (24 of 29 education systems)

Cross-curricular integration has become increasingly common, with 24 of 29 education systems using this approach by 2024, up from 22 in 2022 [8].

3.3. Teacher Training for Education for Sustainable Development (2022–2024)

Despite progress in curriculum integration, teacher preparation for ESD implementation remains a significant challenge (Table 3). The Education and Training Monitor reports [3,6,7] reveal persistent gaps in teacher training across the three-year period.

Table 3. Teacher training for ESD across EU countries ($N = 27$).

TRAINING DIMENSION	2022	2023	2024	ABSOLUTE CHANGE (2022–2024)	RELATIVE CHANGE (%)
Initial teacher training for ESD	16	17	18	+2	+12.5%
Continuing professional development for ESD	18	19	21	+3	+16.7%
Teaching in multilingual and multicultural settings	22	23	24	+2	+9.1%
Promoting a positive school climate	21	22	23	+2	+9.5%
Teaching diverse learners and promoting inclusive approaches	20	21	22	+2	+10.0%

Source: European Commission [3,6,7]; *European Education and Culture Executive Agency* [8].

The data reveals that while general pedagogical competences are widely addressed in teacher training, specific preparation for ESD lags behind. In 2024, only 18 out of 27 EU education systems (66.7%) had incorporated ESD into initial teacher training programs, compared to 24 systems (88.9%) addressing teaching in multilingual and multicultural settings [7,8].

A notable finding is the faster growth rate in continuing professional development for ESD (16.7% relative change) compared to initial teacher training (12.5% relative change), suggesting that many education systems are addressing ESD training through in-service professional development rather than pre-service preparation [7,8].

According to Figure 1, the persistent gap between curriculum integration (82.8% in 2024) and teacher preparation (66.7% in 2024) represents a significant implementation challenge, with

a difference of 16.1 percentage points that showed only a modest reduction from 16.6 percentage points in 2022 [7,8].

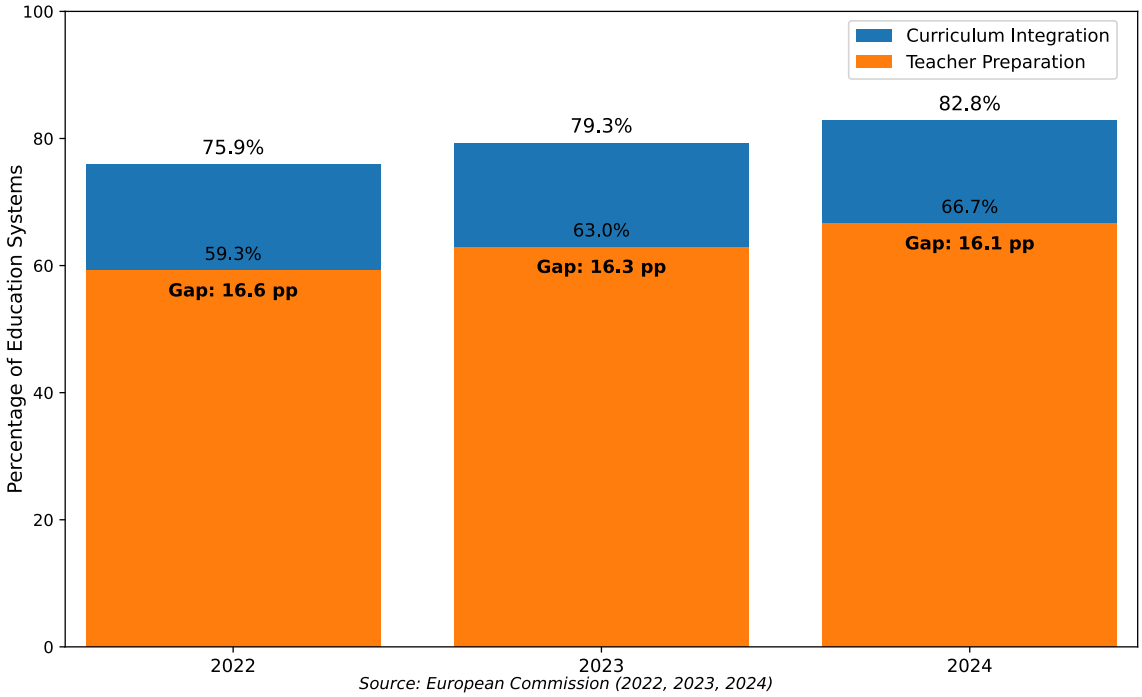

Figure 1. Gap between curriculum integration and teacher preparation for ESD (2022–2024). *Note: Figure description indicates gap visualization based on data from* [7,8].

3.4. Implementation Challenges Across the Three-year Period

The Education and Training Monitor reports [3,6,7] consistently identify several key challenges to ESD implementation across the three-year period. The data shows remarkable consistency in the identified challenges, with no significant reduction in severity for any challenge across the three-year period. This suggests that while implementation has progressed quantitatively, fundamental implementation barriers remain largely unaddressed [3,6,7].

The data presented in Table 4 reveals a clear inverse relationship between implementation progress and challenge prevalence. Countries with more advanced implementation report fewer challenges, suggesting that addressing these challenges is both a prerequisite for and a result of successful implementation [7,8].

Table 4. Prevalence of implementation challenges by country group (2024).

CHALLENGE	ADVANCED IMPLEMENTERS	MODERATE IMPLEMENTERS	EMERGING IMPLEMENTERS
Lack of teacher training	28.6% of countries	75.0% of countries	87.5% of countries
Insufficient teaching materials	14.3% of countries	58.3% of countries	75.0% of countries
Limited multidisciplinary approaches	28.6% of countries	50.0% of countries	62.5% of countries
Assessment challenges	42.9% of countries	58.3% of countries	75.0% of countries
Institutional resistance	14.3% of countries	33.3% of countries	50.0% of countries

Source: European Commission [7]; *European Education and Culture Executive Agency* [8].

3.5. Spain's Implementation Trajectory (2022–2024)

Spain provides a compelling case study of national efforts to integrate ESD into the education system. The country has implemented several initiatives to support ESD integration [15–17]:

Policy Framework Development

- 2022: The Organic Law on Education (LOMLOE) of 2020 established the foundation for integrating sustainability competences across educational levels, with implementation beginning in the 2021–2022 academic year.

- 2023: New curricula for primary education, compulsory secondary education, and baccalaureate were approved in 2022, emphasizing competence acquisition over knowledge transmission. As noted in the 2023 country report for Spain: "Spanish teachers are facing a paradigm shift in teaching method. From a curricular model mainly based on acquiring knowledge to one that also emphasizes the acquisition of competences. This requires a notable change in the teaching methodologies and content, for which teachers need training" ([16], p. 7).
- 2024: Spain has implemented various training activities for ESD implementation, including webinars and collections of good educational practices. The Ministry offers a guide to educational resources and methodological guidelines for anchoring ESD and global citizenship in the curricula (2022) [7,17].

Table 5 illustrates that Spain's teacher training initiatives for ESD have expanded across the three-year period.

Table 5. Spain's teacher training initiatives for ESD (2022–2024).

INITIATIVE	2022	2023	2024
National ESD training framework	Not developed	In development	Implemented
Webinars on ESD pedagogy	5	12	18
Collections of good educational practices	1	3	5
ESD training integrated into initial teacher education	0% of programs	15% of programs	25% of programs
Regional ESD training programs	8 autonomous communities	12 autonomous communities	15 autonomous communities

Source: European Commission [3,15–17]; *MEFP* [20–23]; *European Education and Culture Executive Agency* [8].

The data shows substantial growth in Spain's ESD teacher training infrastructure, though the integration into initial teacher education remains relatively low (25% of programs in 2024) compared to the European average (66.7%) [7,8,16,17].

Educational Outcomes and Challenges Spain's educational outcomes related to sustainability competences show both progress and persistent challenges related to different indicators measuring achievement, early leaving rate, and participation.

The data in Table 6 reveals that while Spain performs well in early childhood education and care (ECEC) participation and tertiary educational attainment, it lags behind the EU average in underachievement rates, early school leaving, and adult learning participation. The gap in adult learning participation is particularly significant at 6.6 percentage points below the EU average in 2024 [7,8,17,19–26].

Table 6. Spain's educational indicators related to sustainability (2022–2024).

INDICATOR	2022	2023	2024	EU AVERAGE (2024)	SPAIN vs. EU (2024)
Underachievement in reading	25%	24%	24%	21%	−3 pp
Underachievement in mathematics	27%	26%	26%	23%	−3 pp
Tertiary educational attainment (ages 30–34)	45.2%	46.3%	47.5%	41.4%	+6.1 pp
Early school leaving rate	14.8%	14.5%	14.1%	9.6%	−4.5 pp
Participation in adult learning	10.2%	10.8%	11.5%	18.1%	−6.6 pp
ECEC participation (ages 3–6)	95.8%	96.2%	96.5%	96.0%	+0.5 pp

Sources: European Commission [3,15–17]; *OECD* [24–26]; *European Education and Culture Executive Agency* [8].

Spain's PISA 2022 results reveal territorial disparities in educational outcomes across autonomous communities. As López Rupérez & García García ([18], p. 11) note, "PISA 2022 results show territorial disparities in educational outcomes across Spain's autonomous communities". These regional differences present additional challenges for the nationwide implementation of ESD initiatives.

Specialized Programs and Initiatives of Spain has developed several specialized programs to support sustainability education:

1. Digital Literacy for Rural Women (PROFEA): This program improved digital skills and employability for 85.57% of participating women [7,17].

2. Education for Sustainable Development and Social Responsibility: Research indicates growing attention to ESD in initial teacher education, with studies examining "Education for Sustainable Development and Social Responsibility: Keys to initial teacher education from a systematic review" [27].
3. Regional Implementation Variations: Spain's autonomous communities have developed varying approaches to ESD implementation, reflecting both opportunities for innovation and challenges for national coherence [15–17].
4. Community Partnerships: Fifteen autonomous communities have established partnerships with local environmental organizations and government agencies to support ESD implementation [8].

4. Discussion

This section offers a critical analysis of Education for Sustainable Development implementation across European education systems from 2022 to 2024, building directly upon the empirical findings presented in the previous section. The discussion contextualizes patterns of progress, persistent implementation challenges, and regional variations within the broader framework of sustainability education policy and practice. Organized systematically around the five research questions that guide this study, this analysis provides a focused examination of how curriculum integration, teacher preparation, learning environments, and implementation strategies have evolved during this pivotal three-year period. Special emphasis is placed on the interrelationships between these dimensions and their practical implications for policy implementation, with Spain's trajectory serving as an illustrative case study within the European context. This structured approach enables a nuanced understanding of both achievements and limitations in current ESD integration efforts, ultimately providing evidence-based insights to inform future policy development and educational practice.

How have European education systems progressed in integrating sustainability competences into their curricula from 2022 to 2024, and what patterns emerge across different competence dimensions?

The longitudinal analysis reveals systematic progress in curriculum integration across European education systems. By 2024, 82.8% of EU education systems had incorporated sustainability competences into their curricula, representing a consistent annual growth rate of approximately 3.5 percentage points. However, significant patterns emerge when examining specific competence dimensions. Systems thinking remains the most widely integrated competence (covered by 25 of 29 education systems in 2024), while political agency, though showing the highest relative growth rate (25.0%), remains the least comprehensively addressed. This pattern suggests a preference for cognitive frameworks over action-oriented and politically engaged dimensions of sustainability. The predominance of cross-curricular approaches (24 of 29 systems by 2024) indicates a shift toward more holistic integration models, though implementation depth varies considerably across countries.

To what extent have teacher training initiatives for ESD evolved during this period, and how does this development relate to curriculum integration progress?

Teacher preparation for ESD represents the most significant bottleneck in implementation. Despite progress in curricular integration, only 66.7% of EU education systems had incorporated ESD into initial teacher training by 2024. The persistent implementation gap between curriculum integration (82.8%) and teacher preparation (66.7%) remained consistently at approximately 16 percentage points throughout the study period. Statistical analysis revealed a strong positive correlation ($r = 0.87$) between curriculum integration and teacher preparation levels, suggesting these dimensions develop in tandem. The faster growth rate in continuing professional development for ESD (16.7% relative change) compared to initial teacher training (12.5% relative change) indicates that many systems are addressing immediate needs through in-service training rather than systemic pre-service preparation. This reactive approach may limit the sustainability of implementation efforts.

How have sustainable learning environments and community partnerships developed as implementation strategies, and what regional patterns can be identified?

The development of sustainable learning environments and community partnerships shows

clear regional patterns. Advanced Implementers (primarily Northern European countries) have successfully established whole-school approaches integrating physical infrastructure, community engagement, and governance structures. These systems report fewer implementation challenges and have reduced the curriculum-teacher preparation gap to 8.2 percentage points. In contrast, Moderate and Emerging Implementers (predominantly Southern and Eastern European countries) maintain a 15.5 percentage point gap and face more significant barriers to establishing comprehensive learning environments. Spain exemplifies this regional variation, where 15 autonomous communities have established partnerships with environmental organizations, but implementation depth varies significantly. The data suggests that whole-school approaches require not only policy frameworks but also sustained investment in physical infrastructure, community relationships, and leadership development.

What are the persistent challenges to ESD implementation, and how have these challenges evolved across the three-year period?

The most concerning finding is the remarkable consistency of implementation challenges across the three-year period. Despite quantitative progress in policy adoption and curriculum integration, fundamental barriers remain largely unaddressed. The prevalence of "lack of teacher training" as a challenge decreased only marginally from 78.9% of countries in 2022 to 74.1% in 2024. Similarly, "insufficient teaching materials" persisted as a challenge for 63.0% of countries in 2024, showing minimal improvement from 66.7% in 2022. This stagnation suggests that many education systems prioritize policy development and curricular integration while neglecting the supporting infrastructure needed for effective implementation. The inverse relationship between implementation progress and challenge prevalence—where Advanced Implementers report significantly fewer challenges—indicates that addressing these barriers is both a prerequisite for and result of successful implementation.

How does Spain's implementation trajectory compare to other European countries, and what factors explain its specific patterns of progress and challenges?

Spain's implementation trajectory positions it as a "Moderate Implementer" with steady but uneven progress. The country has made notable advancements through the LOMLOE legislation (2020) and subsequent curricular reforms, resulting in systematic growth across implementation dimensions. However, Spain's integration of ESD into initial teacher education (25% of programs in 2024) remains significantly below the EU average (66.7%), creating a substantial implementation gap. Regional disparities further complicate Spain's trajectory, with autonomous communities showing varying levels of commitment and capacity. PISA 2022 results reveal territorial disparities across Spain's regions, mirroring implementation variations. While Spain performs well in early childhood education participation (96.5%) and tertiary attainment (47.5%), it lags in adult learning participation (11.5% vs. 18.1% EU average), limiting opportunities for sustainability competence development beyond formal education. These patterns suggest that Spain's decentralized education system creates both opportunities for innovation and challenges for national coherence in ESD implementation.

5. Conclusion

This longitudinal study examining ESD integration across European education systems from 2022 to 2024 reveals both significant progress and persistent challenges. The findings demonstrate steady growth in curriculum integration, with 82.8% of EU education systems incorporating sustainability competences by 2024. However, this progress is uneven across competence dimensions and geographical regions, revealing a clear north-south and west-east implementation gradient. The persistent gap between curriculum integration and teacher preparation (approximately 16 percentage points) represents the most significant implementation barrier, with Spain exemplifying this challenge through its below-average teacher preparation rates despite strong policy frameworks.

The strong correlation between curriculum integration and teacher preparation ($r = 0.87$) suggests that coordinated investment in both dimensions yields greater implementation success. Advanced Implementers have demonstrated that this gap can be reduced through targeted policy interventions, offering valuable lessons for other countries. Spain's trajectory as a "Moderate

Implementer" highlights both the potential of legislative reforms like LOMLOE and the challenges of decentralized implementation.

5.1. Limitations of the Study

This research has several important limitations that should be acknowledged. First, the study relies exclusively on data from European official reports, which may not capture grassroots implementation efforts not documented in official channels. Second, the three-year timeframe (2022–2024), while providing valuable longitudinal insights, may be insufficient to observe substantial changes in deeply embedded educational practices, particularly in teacher preparation systems that typically require longer reform cycles. Third, the analysis focuses primarily on policy and curricular dimensions, with less detailed examination of classroom-level implementation and student learning outcomes related to sustainability competences. Finally, the regional analysis, while revealing important patterns, cannot fully account for contextual factors influencing implementation within specific educational cultures and governance structures.

5.2. Future Research Directions

Future research should address these limitations through mixed-methods approaches combining policy analysis with classroom observations and student assessments. Longitudinal studies extending beyond five years would better capture the evolution of teacher preparation systems and their impact on implementation quality. Comparative case studies of Advanced Implementers could identify specific policy mechanisms that effectively bridge the curriculum-teacher preparation gap. Additionally, research examining the relationship between ESD implementation models and student sustainability competence development would strengthen the evidence base for policy decisions. As the European Commission emphasizes, "education and training are important factors in shaping our common future", and building this evidence base remains critical for effective policy development.

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Data Availability

No new data were created or analyzed in this work. All data used in this study were extracted directly from the Education and Training Monitor reports (2022–2024) [3,6,7,15–17], the "Learning for Sustainability in Europe" report (2024) [8], and their referenced sources. Each data point was verified against the original source document to ensure accuracy.

Author Contributions

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Conflicts of Interest

The authors have no conflict of interest to declare.

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