

Integrating Environmental Education into the School Curriculum and the Use of Digital Tools in Ecological Awareness

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Abstract. This study examines the integration of environmental education (EE) into the school curriculum and the contribution of digital tools to ecological awareness, drawing on research carried out within the Erasmus+ project Clean Environment – Clean School Climate with Creative Environmental Practices in School Education. Adopting a mixed-methods design, it combines a qualitative synthesis of disciplinary case studies with a quantitative survey of 244 participants concerning their sources of environmental information, self-assessed ecological knowledge, and perceptions of digital applications and games. The qualitative strand shows that EE can be embedded meaningfully across ten school subjects, from the natural sciences and mathematics to the humanities and the arts, provided that teaching is adapted methodologically and teachers are appropriately trained. The survey indicates that school remains the dominant source of environmental information (84.4%), that ecology-themed online games are widely regarded as effective (70.9%), yet that a majority (56.6%) judge the contribution of digital applications to durable behavioural change to be limited. These findings expose a recurring gap between ecological knowledge and ecological behaviour and suggest that digital tools are most effective as complements to experiential and community-based learning rather than as substitutes for it. The study concludes with evidence-based recommendations at the policy, institutional and technological levels, and argues that authentic interdisciplinarity, supported by adequate teacher training and school–community partnerships, is a precondition for effective and sustainable environmental education in formal settings.

Keywords: Environmental education; Interdisciplinary curriculum; Digital tools; Sustainability; Erasmus+; Ecological awareness.

1. Introduction

The ecological crisis is among the defining challenges of the twenty-first century, and any systemic response to it depends in part on the reform of education. Environmental education (EE) – understood as the process of forming the knowledge, values and competences needed to understand and address environmental problems – has acquired a growing place in international educational policy, notably within target 4.7 of the United Nations Sustainable Development Goals, which calls for education for sustainable development and sustainable lifestyles (Fang et al., 2022).

The urgency of this agenda is underlined by the persistence of the chemical and environmental legacies inherited from earlier industrial decades, which continue to shape present-day risks and demand an ecologically literate citizenry capable of informed judgement (Arp et al., 2023). In this

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context, schools are increasingly expected not merely to transmit factual knowledge about the environment but to cultivate the dispositions and behaviours associated with sustainability.

The present study draws on the Erasmus+ project Clean Environment – Clean School Climate with Creative Environmental Practices in School Education (grant 2023-1-NO01-KA220-SCH-000159229), a transnational framework within which teachers, researchers and students explored concrete ways of embedding EE in school practice. It synthesises and critically analyses the principal findings presented at the project conference, organised around two themes: the interdisciplinary integration of EE across the curriculum, and the impact of digital tools on ecological awareness.

By bringing together a qualitative reading of disciplinary practice and a quantitative survey of participants' perceptions, the study aims to clarify both where EE can be embedded and how digital tools can best support it. Its significance lies in offering evidence-based guidance for schools seeking to make environmental education authentic, interdisciplinary and durable rather than symbolic.

The study pursues four objectives: first, to identify the benefits and challenges of integrating EE across different school subjects; second, to analyse participants' perceptions of their sources of environmental information and their level of ecological knowledge; third, to evaluate the effectiveness of digital tools, including applications and online games, in fostering sustainable behaviours; and fourth, to formulate evidence-based recommendations for implementing EE in formal educational settings.

2. Research methodology

The study adopts a mixed-methods design that combines qualitative and quantitative strands. The qualitative strand consists of a thematic synthesis of the specialist literature and of the disciplinary case studies presented at the CLEAN project conference, organised by school subject. The quantitative strand draws on a survey administered to a sample of 244 participants, comprising students, teachers and education specialists.

Data were collected through an electronically administered questionnaire combining multiple-response items and Likert-type scales. The instrument addressed four areas: the sources from which respondents obtain environmental information; their self-assessed level of ecological knowledge; their perception of the effectiveness of ecology-themed online games; and their view of the contribution of digital applications to sustainable behaviour. Respondents were also asked to identify the school subjects in which ecological digital applications would be most useful.

Responses were analysed descriptively, with results expressed as percentages of the sample; because several items permitted multiple responses, the percentages do not sum to one hundred. The qualitative and quantitative findings were then read together to support interpretation. As an exploratory, single-project study based on a convenience sample and self-reported perceptions, the research does not claim statistical representativeness or causal inference, a limitation revisited in the conclusion.

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3. Environmental education across the school curriculum

Evidence from the CLEAN project indicates that EE can be integrated authentically across all curricular areas, provided that appropriate methodological adaptation is in place. Table 1 summarises the principal benefits and challenges identified for ten school subjects.

Table 1. Integration of environmental education across school subjects: benefits and challenges (synthesis based on CLEAN project research, school year 2024–2025).

Subject	Principal benefits	Challenges and obstacles
Biology	Direct connection with ecosystems; critical thinking; lasting sustainable behaviours	Limited resources; need for teacher training; balancing with standardised testing
Chemistry	Practical applications of green chemistry; pollution problem-solving; sustainable chemistry	Curriculum adaptation; lack of specific training; integration with classical content
Geography	Linking global issues to local realities; use of GIS; active citizenship	Limited access to technology; need for up-to-date data; pressure of testing
Mathematics	Mathematical modelling of the environment; applied statistics; interdisciplinary thinking	Perception that EE diverts from core content; teacher preparation
Physical education	Outdoor activity; the health–environment link; eco-friendly transport	Access to natural spaces, especially in urban areas; resources for outdoor activity
Music	Emotional connection with nature; composition from natural sound; eco-instruments	Balancing with classical music education; interdisciplinary teacher training
Philosophy	Ethical debate; eco-philosophy; intergenerational justice; global citizenship	Excessive abstraction; difficulty connecting to students' direct experience
Literature	Literary ecocriticism; emotional connection; creative writing on environmental themes	Traditional literary canons; difficulty sourcing eco-relevant texts
History	Historical roots of the crisis; environmental justice; lessons from the past	Priority of political and social content; limited relevant regional resources
Visual arts	Visual advocacy; recycled and eco materials; art as a tool for awareness	Cost of eco-friendly materials; resistance to changing established practice

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3.1 The natural sciences and mathematics

Biology and chemistry offer the most direct connection to environmental education. In biology, EE allows students to grasp the interconnectedness of living systems, the human impact on biodiversity and the principles of conservation. The evidence reviewed in the project indicates that experiential activities – field trips, practical experiments and ecosystem-monitoring projects – markedly increase both engagement and the retention of knowledge (Jeronen et al., 2016; Otto & Pensini, 2017). In chemistry, concepts such as green chemistry, industrial waste management and renewable energy provide fertile ground for applying the principles of sustainability, while problem-based projects on reducing plastic waste or identifying biodegradable materials foster creativity and ecological responsibility (Teksoz et al., 2010; Fang et al., 2022). The chemical legacy documented by Arp et al. (2023) further illustrates why a chemically literate, environmentally aware citizenry matters. Mathematics, often overlooked in this context, holds considerable potential for statistical modelling and the analysis of environmental data: projects built on real datasets concerning carbon emissions, water consumption or population growth demonstrate the relevance of mathematical reasoning to understanding and addressing ecological challenges (Barwell, 2018).

3.2 The social sciences and humanities

The social sciences and humanities contribute to ecological awareness in ways that extend well beyond the transmission of factual knowledge. Philosophy provides a framework for fundamental ethical debate – whether nature possesses intrinsic or merely instrumental value, and what moral obligations the present generation owes to those that follow – making concepts such as ecocentrism, biocentrism and intergenerational justice into instruments of critical reflection (Kato, 2015; Campbell, 2023). Literature, through its narrative and affective power, can reshape students' perceptions of the human–nature relationship; works in the tradition of Rachel Carson's *Silent Spring* or Richard Powers's *The Overstory* convey the consequences of environmental degradation far more profoundly than the bare presentation of scientific fact (Gandotra & Agrawal, 2020; Van Anh, 2019). History supplies a temporal perspective on the roots of the crisis – the agrarian and industrial revolutions, colonisation and the exploitation of natural resources – helping students see that present challenges are not accidental but the cumulative result of human decisions (Carter & Simmons, 2010). Geography occupies a pivotal position, connecting global problems to local realities through place-based learning, geospatial technologies and the cultivation of spatial citizenship (Israel, 2012; Sebastián López et al., 2023).

3.3 The arts and experiential settings

The arts enrich environmental education with a creative and emotional dimension that supports the move from awareness to engagement. Composing music inspired by natural sound, building installations from recycled materials or producing posters for visual advocacy can transform students from passive recipients into active agents of change (Publicover et al., 2018; Savva et al., 2004). Approaches that integrate the arts with the sciences, in the spirit of STEAM education, strengthen interdisciplinary connections and broaden the appeal of ecological themes (Liao, 2016), while informal and participatory pedagogies in music education foster the affective attachment on which durable values often rest (Green, 2017). Physical education contributes

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through outdoor activity and an explicit linking of human health to environmental health (Welch et al., 2021), and out-of-school settings such as natural history museums offer powerful experiential complements to classroom instruction (Mujtaba et al., 2018). Across these subjects the recurring lesson is that the principal barrier to integration is professional rather than curricular: content can be adapted, but teachers require specific preparation for the interdisciplinary teaching of EE.

4. Digital tools and ecological awareness: survey findings

Within the CLEAN project, a questionnaire was administered to 244 participants in order to assess perceptions of environmental information sources and the usefulness of digital applications. The principal findings are reported below.

4.1 Sources of environmental information

The data reveal a clear hierarchy among the sources of environmental education accessed by participants (Table 2). School was identified as the primary source by 84.4% of respondents, confirming the central role of the educational institution and the corresponding responsibility it carries. The complementary weight of mass media (63.1%) and social networks (47.1%) suggests that a strong digital echo can amplify ecological messages first conveyed in formal settings. The low reliance on NGO campaigns (7.0%) points to an under-exploited potential for collaboration between schools and civil society, partnerships that, according to the project's findings, can bring additional resources and practical expertise.

Table 2. Distribution of environmental information sources (N = 244; multiple responses permitted).

Source of information	Percentage (%)	Responses (n)
School / educational institution	84.4	206
Mass media (TV, print, podcasts)	63.1	154
Social networks	47.1	115
Extracurricular activities (volunteering, experts)	26.2	64
NGO campaigns	7.0	17

4.2 Self-assessed ecological knowledge

Asked to assess their own level of environmental knowledge, 52.9% of participants rated it as good, 33.6% as satisfactory, 11.5% as very good and 2.0% as low. That more than 86% placed themselves in the good or satisfactory categories suggests a solid informational base, plausibly attributable to access to formal education. The small proportion reporting a very good level (11.5%), however, indicates a deficit in more advanced understanding – an aspect that EE programmes might address through more specialised and interactive content.

4.3 Perceived effectiveness of ecology-themed online games

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A key question concerned the value of ecology-themed online games as educational tools. Here 70.9% of participants considered them effective and a further 14.8% very effective, while 14.3% regarded them as ineffective. Although the predominantly positive judgement (85.7% effective or very effective) validates the potential of gamification in EE, the gap between effective and very effective suggests that current game design does not fully maximise educational impact, and the non-negligible 14.3% who found such games ineffective raise questions about the quality of the ecological content and the relevance of the scenarios offered.

4.4 The impact of digital applications on sustainable behaviour

Perceptions of the contribution made by digital applications to sustainable behaviour were more reserved: 56.6% judged it to be small, 38.9% considerable and 4.5% non-existent. This apparent tension with the favourable view of online games suggests that participants distinguish between the immediate educational value of applications – conveying knowledge and stimulating interest – and their capacity to produce durable behavioural change. The distinction is pedagogically significant: cognitive effectiveness does not automatically translate into behavioural effectiveness.

4.5 Subjects recommended for ecological digital applications

Finally, participants identified the subjects in which ecological digital applications would be most useful (Table 3). The dominance of geography (72.1%) and the sciences (56.6%) reflects the traditional perception of EE as belonging primarily to subjects with a direct link to the natural environment. The notable presence of history (33.6%) and foreign languages (29.1%) signals an openness to interdisciplinary approaches, whereas the low ranking of mathematics (18.4%) confirms its persistent – and, on the project’s evidence, mistaken – image as a subject unrelated to the environment.

Table 3. Subjects recommended for integrating ecological digital applications (N = 244; multiple responses permitted).

Subject	Percentage (%)	Responses (n)
Geography	72.1	176
Sciences (biology, chemistry, physics)	56.6	138
History	33.6	82
Foreign languages	29.1	71
Literature	24.2	59
Philosophy	23.0	56
Visual arts	20.5	50
Mathematics	18.4	45
Physical education	10.0	24

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5. Discussion

5.1 The knowledge–behaviour gap

Read alongside the specialist literature, the data support conclusions that go beyond mere description. A recurring theme is the gap between ecological knowledge – self-assessed as good or satisfactory by 86.5% of participants – and the actual adoption of sustainable behaviours. This phenomenon, known in the literature as the attitude–behaviour gap, indicates that the transmission of knowledge is not by itself sufficient to generate durable behavioural change (Gifford & Nilsson, 2014). The project’s findings suggest that approaches grounded in direct experience – field trips, community projects and practical activities – and in emotional engagement through music, literature and the arts are more effective in bridging knowledge and action than purely theoretical instruction (Otto & Pensini, 2017).

5.2 The complementary role of technology

The results also confirm that digital tools play a complementary rather than a substitutive role. The fact that 56.6% of participants rated the contribution of applications to sustainable behaviour as small should not be read as a failure of digital provision but as an invitation to improve it. Applications excel at stimulating interest and conveying information; they are less effective at generating practical engagement and long-term behavioural change. The optimal model suggested by the project is one of complementarity, in which digital applications are embedded within broader educational strategies that also include experiential activities, community projects and inter-institutional collaboration.

5.3 Interdisciplinarity from principle to practice

Finally, the project demonstrates that interdisciplinarity in EE is not an abstract ideal but an implementable reality. Subjects apparently distant from environmental themes – philosophy, music, the visual arts, mathematics – proved able to contribute authentically and significantly to ecological awareness, provided that teaching was adapted and teachers adequately prepared. The principal barrier is therefore professional rather than curricular: teachers need specific training in the interdisciplinary teaching of EE, a need only partly met by the project’s own professional-development activities.

6. Evidence-based recommendations

6.1 Educational policy

At the level of educational policy, the evidence supports introducing EE as a compulsory cross-curricular domain with clear objectives in national framework curricula; allocating the resources – budget, equipment and outdoor space – required for experiential activities; establishing a framework for systematic collaboration between schools and environmental organisations, NGOs and research institutions; and incorporating EE as a competence area within teacher-education standards.

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6.2 The school level

At the institutional level, schools would benefit from developing subject-specific plans for integrating EE, with measurable objectives aligned to the curriculum; from organising interdisciplinary training for teachers, including through partnerships with international projects such as Erasmus+; from forming partnerships with nature reserves, natural-history museums and community organisations for fieldwork; and from monitoring the impact of EE activities on students' behaviour.

6.3 Digital tools

With respect to digital tools, the findings argue for developing interactive applications with realistic scenarios and immediate feedback that prompt concrete action; for integrating gamification with mechanisms that transfer learning into reality, such as real ecological challenges and school–community projects; for using collaborative citizen-science platforms in international environmental-monitoring projects; and for systematically evaluating the long-term behavioural impact of digital applications.

7. Conclusions

The Erasmus+ project Clean Environment – Clean School Climate with Creative Environmental Practices in School Education shows that integrating environmental education into the school curriculum is not only desirable from the standpoint of global sustainability but also feasible pedagogically, across all curricular areas and levels of schooling. Three principal conclusions emerge. First, the school remains the central actor in transmitting ecological knowledge – identified as the primary source by 84.4% of participants – and therefore bears a major responsibility for the quality and relevance of that education. Second, authentic interdisciplinarity, rather than its formal simulation, is a precondition for effective EE: every subject, from mathematics to music, can and should contribute to ecological awareness. Third, digital technology is a complementary instrument rather than a complete solution; the real but under-exploited potential of applications and online games is realised only when they are embedded in coherent educational strategies that combine direct experience with community action.

These conclusions should be read in light of the study's limitations: it is based on a single project and a convenience sample, relies on self-reported perceptions, and does not permit causal inference, so its quantitative findings are indicative rather than representative. Future research could usefully test the proposed framework across larger and more diverse samples and over time. Even so, the project demonstrates that change is possible not through isolated interventions but through a systemic, collaborative and interdisciplinary commitment to education for a sustainable future.

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