

Review

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New Insights for Teaching the One Health Approach: Transformative Environmental Education for Sustainability

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Review

New Insights for Teaching the One Health Approach: Transformative Environmental Education for Sustainability

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Abstract: The One Health approach often reaches classrooms through Environmental Education (EE), which aims to guide society's response to current crises (environmental, health, economic, values). However, traditional EE teaching has focused on isolated ecological concepts and standardized solutions, ignoring the multidimensional nature of EE and failing to integrate the interdependence between environmental, animal, and human health. Moreover, teacher training often neglects didactic content knowledge, preventing students from acquiring the systemic vision needed to address eco-social problems and create sustainable solutions aligned with the Sustainable Development Goals (SDGs). This limits teachers' ability to influence students' concerns and behaviours. In this context, this study aims to reflect on the current state of the issue and propose strategies informed by Science Education research to improve EE teaching, enabling the integration of One Health dimensions through effective didactics to achieve Transformative Environmental Education (TEE). For this purpose, we begin by addressing the limitations identified in recent systematic reviews, shifting the paradigm towards a symbiosis of EE and Science Education through scientific practices. We then present practical examples showcasing successful EE initiatives that foster a deeper understanding of socio-environmental issues, encourage innovative solutions, and nurture engaged citizens from early education onwards. These proposals can support classroom practice and ongoing teacher self-development. Pedagogical strategies include tackling issues that require systemic and critical thinking by developing scientific and epistemic practices while raising awareness of environmental justice. Thus, this study advocates for a new vision of EE, integrating the One Health approach, which could be applied to develop new educational programs, including teacher training. This would lead to a new learning evaluation model and help identify key determinants that trigger pro-environmental behaviours.

Keywords: education for sustainability; GreenComp; LifeComp; one health; scientific practices; systems thinking; TeachComp; transformative environmental education

1. Introduction

As early as 2004, the Wildlife Conservation Society proposed 12 priorities (Manhattan Principles) to combat threats to human and animal health. From these, the concept "One Health, One World™" was established [1], which evolved into the current One Health approach promoted by FAO, WOA and WHO [2]. This term constitutes a concept of health that goes far beyond the absence of clinical disease, and therefore should not be addressed solely within the healthcare domain, but also through health education as a cross-cutting theme at all educational levels.

Thus, the One Health approach encompasses three interconnected and interdependent dimensions (Figure 1): human health, animal health, and environmental health [3–11].

Human health is defined as the physical, mental, and social well-being of humans. Animal health should be considered similarly, encompassing the well-being of all consumers within the food web (animals other than humans). Lastly, environmental health should be understood as the state of

the ecosystem where the flow of matter and energy occurs correctly. In this context, this third dimension of One Health includes all abiotic factors (physical and chemical), producers in the food web (plants, and autotrophic microorganisms), and other biological agents of the ecosystem that are neither human nor animal (e.g., fungi, protozoa, prokaryotes). The latter are crucial because they refer to a multitude of microorganisms, including viruses and bacteria, which play fundamental roles in ecosystem dynamics and global health. Recognising the importance of these microorganisms is essential for understanding the complex interactions that affect the health of all living beings and for developing effective strategies for disease prevention and control.

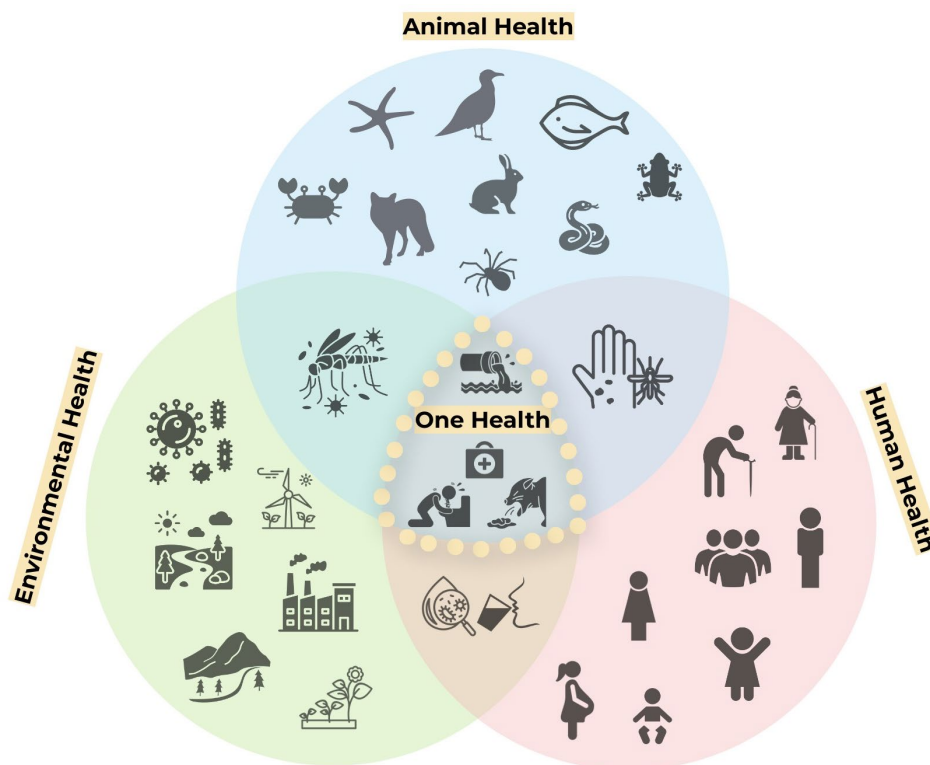


Figure 1. Image representing the interconnection and interdependence among the three dimensions of One Health: human health, animal health, and environmental health.

Examples of the interconnection between habitat destruction, sustainability, and One Health are manifold [5]. One of the most recent would be the COVID-19 pandemic [9], which is linked to situations [12] such as deforestation (SDG 15), the wildlife trade (SDGs 8, 11, 12, and 15), the economy of impoverished regions in Southeast Asia (SDGs 1, 8, and 10), healthcare (SDG 3), and low-quality education (SDG 4).

Similar examples would be situations such as the emergence of vector-borne emerging diseases like West Nile virus [5], Zika and Chikungunya viruses, or malaria plasmodium (SDG 3), easily transmitted in large cities (SDG 11) by mosquitoes lacking predators (bats, frogs, sparrows, spiders, and so on) in urban environments (SDG 15). This underscores the importance of a healthy ecosystem to sustain urban biodiversity that controls the emergence of new disease-transmitting species [13,14].

Lastly, another case could be the emergence of thawing pathogens (SDGs 3 and 15) from permafrost due to global warming (SDGs 7 and 13), becoming active and affecting other living beings. For instance, the outbreak of *Bacillus anthracis* in Siberia from thawed reindeer carcasses over a century old [15]. This incident affected numerous reindeer and a group of people living in the area, suggesting a potential risk of new pandemic pathogens emerging, given the discovery of dozens of giant viruses frozen for over 30,000 years in Siberian permafrost in recent years [16].

In this new context, citizens need to be educated about the origins of recent health crises such as Ebola, Zika, SARS, and avian and swine influenza in order, where possible, to try to prevent the emergence of new ones [14,17]. These examples underscore how environmental degradation and resource overexploitation facilitate the emergence of diseases that harm population health and require a systemic vision to be understood and addressed [18]. The current situation, primarily driven by greenhouse gas emissions over the last two centuries, has altered the atmospheric composition and raised the planet's average temperature [19,20]. Consequently, this has led to changes in ecosystem water regimes, melting ice caps, and rising sea levels [21]. Furthermore, the use of cosmetic, phytosanitary, and pharmaceutical products, along with the discharge of chemical waste from industrial, domestic, and agricultural activities, leads to the accumulation of pollutants in the soil [22–24], surface and groundwater [25–28], and even within the food web [29–31]. This accumulation poses significant concerns for human, animal, and environmental health [32].

All these stresses on ecosystems disrupt the homeostasis of living organisms, causing severe harm and limiting their survival [33]. These changes occur so rapidly that evolutionary adaptations cannot keep pace with the new conditions. So much so that the planet's biodiversity has been drastically reduced in recent years [34], and this process is accelerating due to the interconnectedness required for the correct flow of matter and energy within ecosystems [33]. As more organisms disappear, the remaining ones face greater challenges to survive. Consequently, environmental health has been severely compromised, with worrying implications for both animal and human health.

It is evident, therefore, that solving these problems is not easy and requires understanding that this crisis is a complex interplay of various environmental issues in the Anthropocene [5,18,20,35,36] such as climate change, biodiversity loss, deforestation, pollution, and resource depletion, among others, all of which are intricately linked (systemic vision). For instance, deforestation is not merely an ecological issue; it is also tied to economic activities, land use policies, and social practices. Similarly, pollution and climate change are interconnected through industrial processes and energy consumption patterns, which are influenced by economic and policy decisions. Therefore, addressing these challenges requires a multidimensional analysis that considers not only ecological factors but also the social, economic, and political dimensions that drive these problems [5,18,35].

It is also essential to define the origins of this environmental crisis, recognising that it is anthropogenic and therefore eco-social [9], and the result of decades of unsustainable human practices and policies [36–39]. In this sense, social demands in response to the environmental crisis of the 1960s called for the equitable redistribution of the benefits and burdens of exploiting and using the natural environment and its resources, leading to the concept of Environmental Justice [37,40,41].

For its part, the term Environmental Education (EE) was also defined [42] to guide society's orderly response to the environmental crisis. This definition proposed that EE should be a multidimensional approach, enabling each individual to fully understand the environment and its connections with society (including the environmental impacts of human actions), and find effective solutions to address environmental problems. This conception has been preserved in various International Conferences on Environmental Education [43–46]. It is worth noting that the most significant change occurred with the publication of the 2030 Agenda [38] and its new paradigm of multidimensionality: the Sustainable Development Goals [39]. Therefore, EE encompasses various dimensions such as ecological, economic, social, cultural, and health. To reach the public, it is necessary for these dimensions to be integrated through another dimension: education. This has two components: pedagogical and didactic. The first organizes at the curricular level the knowledge that must be acquired at each educational stage; the second defines the appropriate strategies and tools in classroom practice to convey a comprehensive model of EE (Figure 2).

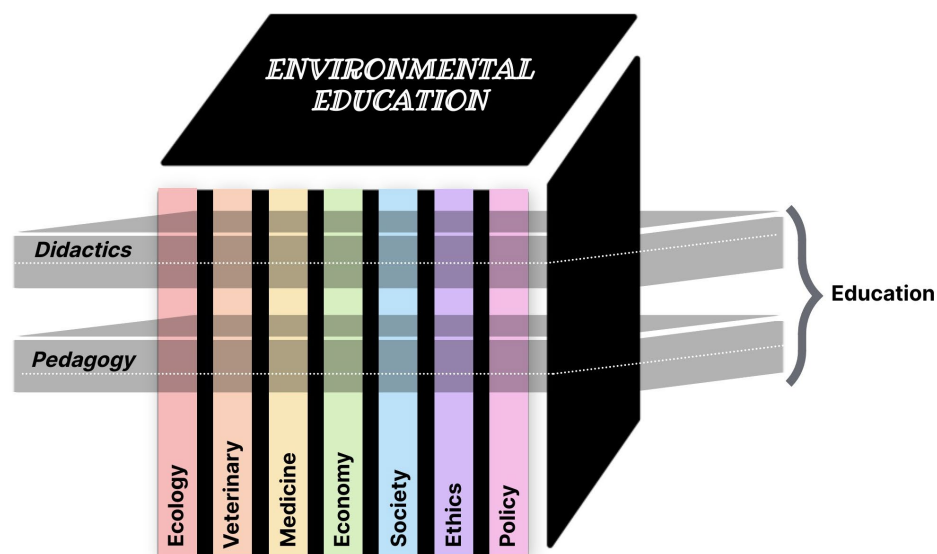


Figure 2. Comprehensive model of Environmental Education representing some of its dimensions and how the educational dimension is responsible for integrating them.

It is important to note that environmental problems are becoming increasingly severe, and EE has not yet been able to reverse the eco-social crisis, as several authors already predicted years ago [47,48]. In this context of unresolved environmental crises and the absence of pro-environmentalism among some citizens (partly due to misinformation that prevents them from acting to protect the environment, and even leading to the denial of issues such as climate change and pandemics) [49], this work aims to reflect on the current state of the issue and propose strategies informed by Science Education research to improve EE teaching, enabling the integration of One Health dimensions through effective didactics to achieve Transformative Environmental Education (TEE).

2. Method

To achieve the reflective and propositional purposes of this work, a three-stage methodological approach was adopted:

1. **Analysis of conclusions from previous systematic reviews and studies proposing effective solutions:** This study extends and complements the theoretical framework by building on two previous systematic reviews [50,51]. These reviews explored how EE has been addressed in high-impact national and international educational research, particularly in Science Education and Education for Social Justice. They also examined the evolution of EE since the publication of the SDGs, highlighting limitations in addressing it from an environmental justice perspective. The conclusions of these reviews identify key problems and limitations within the EE framework, including the traditional focus on isolated ecological concepts and the lack of sufficient didactic training for teachers. From them, we can infer that there is an ineffective integration of the One Health approach into EE. Analyzing these limitations helps to understand the factors hindering the educational impact of current EE strategies and how these issues obstruct the promotion of sustainable behaviors. This situation could be improved if strategies advocated by Science Education research, such as learning based on scientific and epistemic practices, were integrated into the classroom culture within the framework of EE (see section 5.4).
2. **Synthesis and reframing of the current state of EE:** The conclusions from the reviewed studies were used to develop a descriptive and critical review of the current state of EE. This review focuses on two fundamental aspects: classroom practice in EE and teacher training in this field.

- Discussion and selection of practical examples:** Building on this new integrative vision, a series of new directions for EE were recommended, emphasizing teacher competencies within the European framework, particularly the pedagogical knowledge of content and the environmental skills necessary in the Anthropocene era. In addition to developing the theory, practical examples of educational activities were proposed, aligned with the principles of TEE. This study clarifies how these activities promote systems thinking, the application of scientific and epistemic practices, and the development of environmental justice awareness, highlighting a selection of common best practices. The examples are based on the method of didactic transposition, which transforms conceptual and competency-based scientific knowledge into specific activity proposals suitable for various educational levels, including teacher training. The rationale for selecting these examples lies in their ability to present students with realistic socio-environmental problems that foster critical thinking, evidence-based argumentation, personal engagement, and the pursuit of solutions. These practical examples aim not only to inform but also to raise students' awareness of their potential role as agents of social change, regardless of the decisions they later make in their daily lives, which fall outside the evaluative scope of formal education.

3. Classroom Practice in Environmental Education: The Road to Its Hegemonic Narrative

To raise awareness and promote conservation behaviours, EE (recently named Education for Sustainability or Education for Sustainable Development) (e.g., [50]) has for years been proposed by society as the main driver of change for unsustainable actions that cause socio-environmental problems [38,39] such as climate change, biodiversity loss, emergence of invasive species, pollution and resource depletion. As mentioned, these issues are all interconnected and require holistic approaches to be addressed.

Therefore, EE is a multidisciplinary and multidimensional area of knowledge [52,53]. In fact, since its origin it has been incorporating any narratives and/or approaches related to the environment into its theoretical framework [50,52]. This voracity to include any aspect of this field has been further boosted by the advent of the hyper-connected Agenda 2030 and the SDGs. As a result, it has evolved into a macroarea of knowledge with a transdisciplinary spirit but a multidisciplinary reality, making it a hodgepodge.

For its part, the One Health approach is rooted in the connection between Veterinary, Medicine and Ecology, and, although its objective is practical (solving real health problems), to be truly understood, these fields must be integrated and addressed together theoretically in the classroom. However, the analysis of current educational curricula shows that EE teaching has focused mainly on the environmental health dimension (ecology-related content) [53,54], and on the human health dimension driven by anthropocentrism (human body content, hygienic practices, healthy eating) [5,55].

In any case, to fully assimilate the One Health approach, it is essential to address the three dimensions in an integrated manner, rather than separately or in pairs (animal-human health; environmental-human health; animal-environmental health). This need has become even more evident in the wake of the COVID-19 pandemic [56]. Despite this being true at the curricular level, traditionally the One Health concept has been more closely tied to the fields of Veterinary and human Medicine, with the primary focus on preventing zoonotic diseases, and with less focus on the role of the environment as a contributing factor to human and animal health [57], even though there are diseases that can be prevented by developing sustainable lifestyles (e.g., responsible consumption, sustainable cities, ecosystem protection). However, the One Health approach has recently been including environmental health-related concerns such as food security, climate change adaptation and biodiversity that reinforce the need to work out the interdependence between its three dimensions [58].

The unsuccessful transition from multidisciplinary to transdisciplinarity in EE when incorporating a new approach, in this case One Health, is likely due to the lack of organization within its internal dimensions, which can only be integrated through education and specifically through

effective didactics (Figure 3). However, as shown in Figure 3, the emphasis has predominantly been on the ecological, economic, and social aspects [52], neglecting other important dimensions (animal and human health, ethics, politics) [36]. For this reason, when EE aims to be the driving force for behaviour change that promotes sustainability and to play its role in citizen literacy within the One Health approach, it often uses ineffective didactic strategies that have been in place for over 50 years [53].

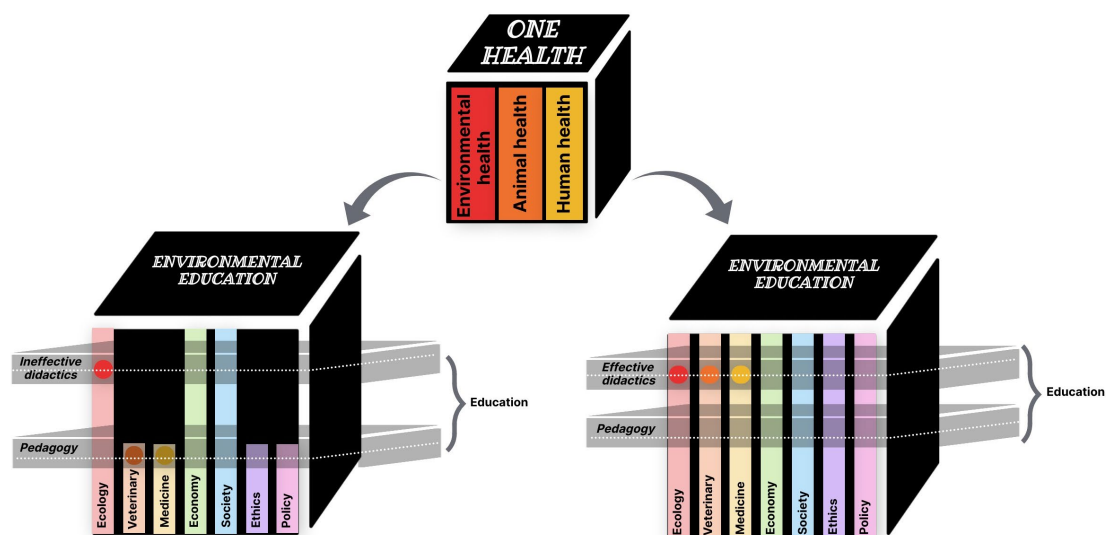


Figure 3. Incorporation of the One Health approach in two opposing models of EE (on the left, an unbalanced model; on the right, an emancipatory/transformatory model), based on the effectiveness of educational practice (didactics). The One Health approach encompasses three interconnected dimensions (coloured columns), all of which must be equally considered. Similarly, the EE model comprises multiple dimensions (coloured columns), seven of which are represented here, and these must also be interconnected for a comprehensive understanding of environmental issues. EE operates on two educational levels: curriculum design (pedagogical component) and classroom practice (didactic component). The pedagogical component can address various dimensions in a transdisciplinary manner, even if these dimensions have imbalances in the model handled by learners (left box). Although training programs emphasize that “everything is connected” and promote transdisciplinary learning, ineffective didactic strategies (Figure 4) can fail to foster these interdimensional connections in practical problem-solving scenarios, making it difficult to develop a full understanding of environmental issues. In a balanced model (right box), where both the pedagogical and didactic components are aligned, effective classroom practices, such as tackling problems that require systems thinking and develop an awareness of environmental justice, enable students to connect different dimensions meaningfully. In short, when the One Health approach is introduced in the classroom, the only way to integrate its dimensions (coloured circles) into students’ mental models, rather than addressing them in a fragmented way, is through the use of effective teaching strategies and a solid understanding of each EE dimension (column height). Thus, an unbalanced EE model, despite its pedagogical intentions, struggles to produce effective learning outcomes because the didactic methods fail to properly integrate these dimensions. Therefore, it is crucial that EE teaching strategies focus on balancing them by connecting content in a transdisciplinary way, rather than treating them separately as traditional approaches tend to do (Figure 4).

These seemingly unsuccessful methodologies (Figure 4) have often merely conveyed the existence of socio-environmental problems and reproduced standard, decontextualized solutions, which are presumed valid for all citizens [51,59,60]. They fail to recognize that people’s actions are based on their individual justifications, motivated by many reasons beyond knowing what should be

done [36,61,62]. Additionally, as standard solutions are often far removed from the interests and willingness to act of citizens, responsibility is frequently shifted to others, with solutions focusing on law and technological advancements [63] that might mitigate environmental degradation (Figure 4). Hence, EE traditional teaching does not align with the needs or the original purpose for which it was created [53].

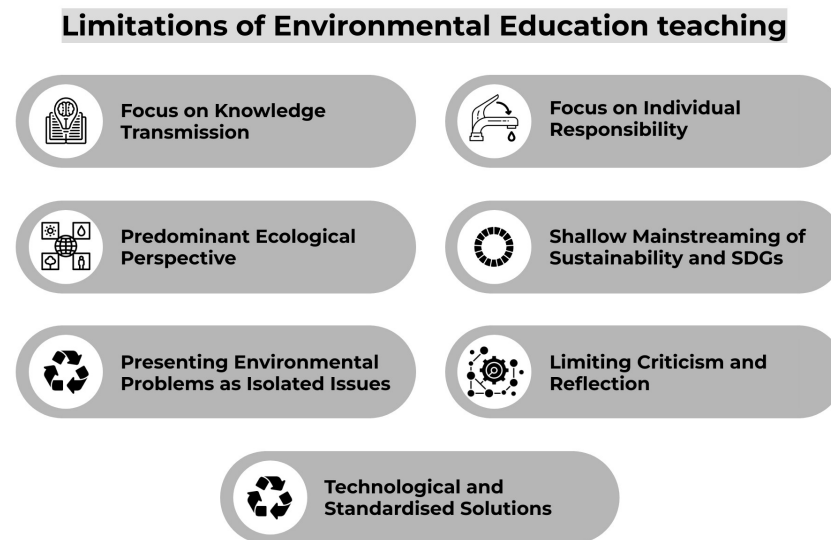


Figure 4. Limitations of traditional EE teaching.

At this point, it should be noted that any key idea from other approaches related to EE field of knowledge, whether complementary or counter-narratives, is incorporated into its theoretical framework [52,64]. However, this incorporation often limits the dissemination of these ideas, as they become “arrested” by EE when ineffective EE educational strategies are applied to teach them. This issue arises from the lack of a successful symbiosis between EE teaching and the teaching practices advocated by international frameworks in Science Education [62], which this study proposes to integrate.

For instance, this “arrest” occurs when typical EE teaching strategies are used to teach the One Health approach, as they often fail to integrate its three dimensions in a holistic way [5,65]. Consequently, as previously mentioned, learning situations related to environmental health are brought into the classroom primarily from an ecological perspective [53,54], and may occasionally be presented from a human health perspective when discussing diseases in topics related to the human body [55].

It should also be pointed out that a hegemonic narrative is a paradigm that is widespread and predominantly accepted by the population [52,64]. In this context, the natural evolution of ideas gives rise to alternative, complementary, or even counter-narratives. When a hegemonic narrative is widely established, it tends to develop mechanisms to avoid being displaced (resistances). Given its body of doctrines, it is capable of incorporating and integrating new narratives into its paradigm, thereby minimising their expansion or significantly limiting their dissemination, and even causing them to disappear over time [52,64]. Therefore, it appears that the traditional EE would be acting as a hegemonic narrative, “phagocytising” the One Health approach (complementary narrative), similar to what has happened with other concepts such as Environmental Justice, Eco-social/Socio-environmental Education, and even the SDGs and Education for Sustainability [50].

In this context, despite previous efforts, it is crucial to enhance the application of the One Health approach in classrooms [5–7]. To achieve this, redefining teacher training in EE is advisable [17,53,63,66,67]. This redefinition should focus on incorporating effective strategies (resources, methodologies) that enhance the didactic dimension of teaching competence (Figure 2), as so far improvements in EE teacher training have primarily concentrated on pedagogical issues (curricular rather than didactic) and conceptual knowledge [53]. As will be discussed below, these strategies

should enable educators to design learning situations that pose realistic socio-environmental problems using a transdisciplinary approach, thus requiring the integration of the three dimensions of One Health that EE has traditionally fragmented (Figure 3).

4. How Is Environmental Education Approached in Teacher Training?

Despite decades of emphasis on the environmental crisis from the educational field, behavioural changes in the population have not occurred and/or have not been sufficient [53]. The recurring limitations identified as the cause are consistently the same: insufficient teacher training in both content knowledge and didactic content knowledge, and the need for high-quality didactic resources that truly impact students [67,68].

EE has traditionally focused on learning ecological concepts [50,51]. This could be attributed to the tendency of many teachers to instruct in the way they were taught and to the fact that initial teacher training has historically overlooked the importance of didactic content knowledge [53]. This situation results in a diminished capacity to effectively influence their future students' concerns and behaviours [50,51,60]. In fact, several studies indicate that teachers lack sufficient training in content knowledge [67,69], despite their training focusing on it, as well as in didactic content knowledge [67,70]. Consequently, focusing teacher training primarily on content rather than its didactics has led to teachers developing a disinterest in science and avoiding science-related content in the classroom. Additionally, due to low didactic content knowledge, teachers often have a low self-perception of their ability to effectively address EE topics beyond basic concepts like recycling [59]. This results in them steering clear of these subjects in their teaching [67].

It is evident that this situation must change, benefiting from the fact that the environmental legislative framework has also evolved since the Paris Agreement. Thus, the European Union's decarbonisation program has compelled member states to enact corresponding laws. For instance, Spain's Law 7/2021 on climate change and energy transition has influenced the development of the new educational law [71], which now includes the One Health approach within the framework of eco-social Education, forcing this integrative vision of health into the classroom. Nevertheless, the regulations governing initial teacher training in Spain date back to 2007 [72,73] and do not adequately prepare professionals for this new context. Therefore, continuous and updated initial teacher training in EE is crucial to delivering effective educational proposals in the classroom. This involves integrating the One Health approach into EE teaching programs, as there are currently few such initiatives (e.g., [17,74]). This reorientation could enhance students' awareness and engagement (sustainable attitudes and behaviours), especially in the early educational stages, where there is greater potential to influence behaviours [75–79].

In this context, and as we will explore in more detail in the next section, there is a growing consensus among educators and policymakers on the need to promote transformative and effective EE teaching [53,67]. This approach aims to empower learners to critically engage with environmental issues, understand their systemic nature, and develop the skills necessary to advocate for sustainable solutions [62,67]. It involves moving beyond merely transmitting information about environmental problems and standardized solutions, towards fostering a deep understanding of issues from multiple perspectives, collaboratively searching for evidence-based solutions, and making informed decisions [17,80].

5. Discussion

5.1. Emphasising the Didactic Dimension of Environmental Education in Teacher Training

As mentioned above, initial teacher education programs in EE have neglected the development of specific didactic knowledge [53], even though they should focus on equipping teachers with the competencies needed to effectively address EE in the classroom. This requires, above all, developing the capacity of teachers to design and implement activities that have an emancipatory/transformative impact on students [80]. Following the European nomenclature of competencies such as *GreenComp* [76] or *LifeComp* [81], this could be referred to as *TeachComp*. These are activities that challenge

students with realistic socio-scientific problems, promoting deeper understanding and students' systems and critical thinking, considering the multidimensionality of environmental problems and reflecting on their complexity, as there are many dimensions (both epistemic and non-epistemic) that influence awareness, decision-making, or informed citizen participation in relation to any socio-environmental issue.

5.2. Integration of *GreenComp* and *LifeComp* Competences in the “*TeachComp*” during Teacher Training

The one coined as *TeachComp* in this work (Figure 5) would include two other competencies that European reference frameworks propose for all citizens, regardless of their profession, and that initial teacher trainees should have already acquired: *LifeComp* [81], which focuses on the development of life skills such as learning to learn, and *GreenComp* [76], which involves developing a basic understanding and practical skills to address environmental challenges from multiple perspectives. This includes implementing sustainable solutions in daily life (e.g., waste reduction, recycling, energy efficiency, use of renewable energy, and adoption of responsible consumption habits), actively participating in community initiatives, and making informed decisions that promote sustainability in various contexts while evaluating the systemic impact of those decisions.

In fact, teachers initial training should focus on developing the didactic dimension of both competences. Thus, *GreenComp* for teachers would involve developing teaching methods that integrate sustainability into the school curriculum and implementing active methodologies that promote scientific practices through the exploration of realistic environmental issues. Teachers should be trained to model and promote sustainable values, inspiring students to adopt an environmental ethic and develop the skills necessary to act sustainably in their daily lives.

Additionally, *LifeComp* for teachers would encompass the development of essential skills for managing personal, social, and professional lives, while preparing students to face the challenges of the 21st century. This includes fostering self-awareness, time and stress management, effective communication, collaboration, critical thinking, efficient problem-solving, uncertainty management, creativity, innovation, civic engagement, ethical responsibility, and the ability to formulate integrated and balanced solutions in a complex and constantly changing world.

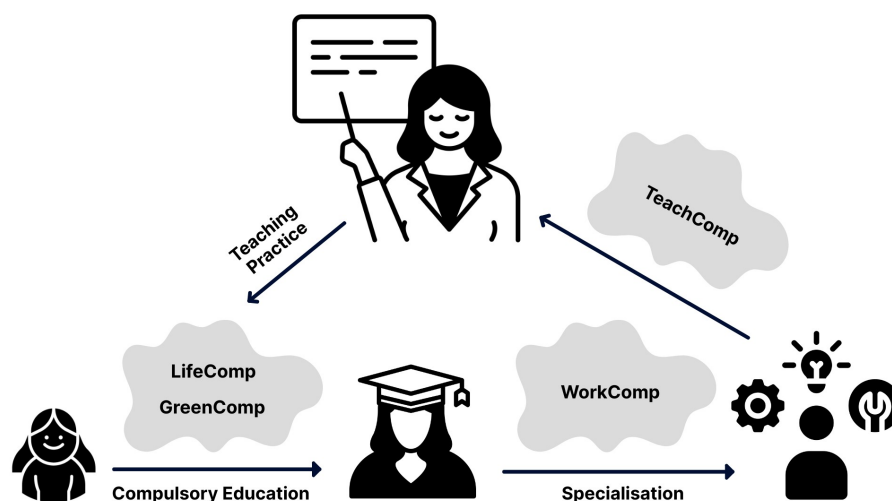


Figure 5. Image depicting the acquisition of *GreenComp* and *LifeComp* competencies by citizens during compulsory schooling, and how these become part of their specialisation in any profession (*WorkComp*). In the case of educators, the *TeachComp* competence they develop would influence how they impart *GreenComp* and *LifeComp* in the classroom.

By incorporating *GreenComp* and *LifeComp* into compulsory education through a TEE approach (Figure 5), educators can empower students (citizens) to not only understand the interconnection

between environmental issues but also to develop skills to effectively address these problems [82]. This approach not only strengthens students' environmental literacy but also prepares them to be informed and committed agents of change for sustainability in their communities, both in their everyday lives and in their professional careers (*WorkComp*).

Furthermore, integrating both competencies into teacher training programs could empower educators to teach about the interconnectedness of environmental and health issues. This approach not only aligns with the One Health paradigm but also prepares students to think critically and act responsibly in tackling global health challenges.

5.3. What Skills Do International Scientific Frameworks Aim to Foster in Today's Citizens?

Promoting TEE requires not only a change in teacher training but also in the very structure of how EE is taught and learned in classrooms [53]. New curricula and transformative educational approaches should focus on developing students' ability to think critically about environmental issues from multiple perspectives and to advocate for positive changes in their communities [63,66,80].

In response to the current context of globalization and crises (environmental, health, economic, values), the Strategic Vision Expert Group (SVEG), tasked with designing the PISA 2025 standardised tests, proposed updating its scientific framework [35]. Thus, the scientific competencies considered in these tests will be threefold: *Explain phenomena scientifically*; *Construct and evaluate designs for scientific enquiry and interpret scientific data and evidence critically*; and *Research, evaluate and use scientific information for decision making and action*. This is particularly relevant today, given that society is 'infodemic' due to the vast amount of data to which it has access, which are not always valid and reliable (misinformation) [49]. When it comes to information labelled as 'scientific' (obtained within and outside formal educational spaces), people often do not doubt its validity or rigor. Even less so if it comes from a researcher or a teacher (authority principle), even if it is not well-founded [83]. However, adequate scientific education should encourage students to remain sceptical of new information, to question whether there are conflicts of interest behind it, whether there is scientific consensus and whether the sources are relevant and reliable [84,85].

Furthermore, the scientific framework of PISA 2025 also proposes to measure the "Agency in the Anthropocene" [35]. This agency requires understanding that human impacts have significantly altered Earth's systems and continue to do so. To measure this, the SVEG suggests considering three competencies in environmental sciences: *Explain the impact of human interactions with Earth's systems*; *Make informed decisions to act based on evaluation of diverse sources of evidence and application of creative and systems thinking to regenerate and sustain the environment*; and *Demonstrate hope and respect for diverse perspectives in seeking solutions to socio-ecological crises*.

To ensure students not only succeed in these tests but also thrive in the world they live in, it is crucial that throughout their compulsory schooling [78], ideally starting from early childhood, they engage in classroom activities that foster the development of these competencies [75,77,79]. In the context of this work, this is especially relevant for addressing issues related to One Health. Therefore, it is essential to promote the One Health approach in the teaching of EE [5], as it is being successfully implemented in some compulsory education initiatives [7,63]. As evidenced in the following section, a didactic method to support this is to integrate scientific and epistemic practices into the usual classroom culture.

5.4. Practical Examples: Redefining the Didactic Approach of Environmental Education towards Transformative Environmental Education

Historical examples, such as Rachel Carson's advocacy for pesticide regulation, most notably through her book *Silent Spring*, highlight the transformative power of individual actions in shaping environmental policies and raising public awareness. Carson's work, which revealed the harmful effects of pesticides like DDT on environmental, human, and animal health, was instrumental in leading to their eventual ban and sparking the modern environmental movement. Introducing such

examples in the classroom enables educators to illustrate the significance of environmental stewardship and inspire students to advocate for sustainable practices in their everyday lives.

To illustrate the practical application of the aforementioned principles, three examples of successful EE initiatives developed by our research team in response to contemporary environmental challenges are presented. These examples seek to integrate the One Health approach into classrooms through effective teaching methods (Figure 3).

5.4.1. Example 1 within the Framework of Primary Education: Activity That Addresses the Problem of Raptors Deficiency in Wetlands and Its Consequences for Human, Animal, and Environmental Health

The chapter titled “Towards Transformative Environmental Education: Effective Activities for Primary Education” [17] aligns with didactic strategies aimed at developing a systemic vision, scientific and epistemic practices, and environmental justice awareness in the following ways:

- **Systems thinking:** The activity is designed to foster a systemic vision of the presented environmental issue that integrates the One Health approach. It requires students to understand the complex ecological relationships and the role of top predators in maintaining ecosystem balance, highlighting the implications of their absence for human, animal, and environmental health (disease transmission).
- **Scientific and epistemic practices:** The activity promotes the development of scientific practices such as inquiry, modelling, and argumentation to enhance the understanding of ecological issues. Students engage in these practices by formulating hypotheses, collecting and analysing data, and constructing increasingly sophisticated scientific arguments and models based on available evidence. This process helps students develop a deeper understanding of scientific concepts and the nature of scientific inquiry (how science is constructed).
- **Awakening environmental justice:** The activity is designed to raise awareness of environmental justice by illustrating how the degradation of wetlands affects organisms, emphasising the importance of preserving ecological balance for the well-being of all species. Environmental degradation, such as climate change, is primarily driven by high-impact actions in hyper-urbanised areas, which ultimately affect more natural rural areas, jeopardising ecosystem balance. Therefore, the inhabitants of these areas suffer the most from the consequences, despite being less responsible for the damage (unequal distribution of the benefits and burdens of environmental harm).

5.4.2. Example 2 within the Framework of Secondary Education: Activity on Reproductive Problems in Animals and Humans Caused by Environmental Contamination from Pesticides

The article titled “Does Pollution Only Affect Human Health? A Scenario for Argumentation in the Framework of One Health Education” [63] aligns with didactic strategies aimed at developing a systemic vision, scientific and epistemic practices, and environmental justice awareness in the following ways:

- **Systems thinking:** The activity enables students to develop a systemic understanding of the interconnections between environmental pollution and the reproductive health of animals and humans by integrating evidence-based argumentation, the One Health approach, and complexity-based solutions. This approach allows students to analyse the multifaceted nature of environmental challenges and propose well-reasoned solutions to reduce pollution and its effects.
- **Scientific and epistemic practices:** The activity emphasises the importance of students applying scientific skills such as identifying relevant data, establishing cause-and-effect relationships, and evaluating evidence to support conclusions. Engaging in evidence-based argumentation within the context of One Health education can enhance students’ scientific reasoning and environmental literacy. Additionally, delving into how scientific ideas are constructed, the role of data and evidence in science (argumentation as a process of critical evaluation and evolution

towards sophisticated models, using evidence to support scientific explanations, and so on), could implicitly improve their epistemic practices.

- Awakening environmental justice: The activity fosters a sense of global citizenship and environmental responsibility by encouraging students to propose solutions that take into account both planetary and human health.

5.4.3. Example 3 within the Framework of Teacher Training: Activity on the Sustainability of Avocado Production and Consumption in the World

The article titled “Is Consuming Avocados Equally Sustainable Worldwide? An Activity to Promote Eco-Social Education in Science Education” [66] aligns with didactic strategies aimed at developing a systemic vision, scientific and epistemic practices, and environmental justice awareness in the following ways:

- Systems thinking: The activity encourages students to analyse the sustainability of avocado consumption from multiple perspectives, including ecological, economic, political, and social aspects. By providing materials that encompass various viewpoints, students are prompted to adopt a holistic view to understand the complexity of the case and make informed decisions about it.
- Scientific and epistemic practices: Through the activity, pre-service teachers must make informed decisions about the sustainability of avocado consumption in countries like Spain (southern regions), considering factors such as resource depletion that may render its continuous production unfeasible. This fosters the development of their scientific reasoning and critical thinking skills, recognising the limitations of the available data for certain claims, the importance of seeking consensus, and the value of considering alternative viewpoints (thus implicitly working on epistemic practices).
- Awakening Environmental Justice: The activity promotes eco-social education by involving students in debates and reflections on environmental justice and sustainability, deepening their understanding of the issues and making them feel engaged in solving environmental problems. The ultimate goal is that the knowledge acquired will lead to changes in everyday behaviour including sustainable use and consumption of resources.

6. Limitations and Future Directions

The study’s limitations may be linked to the methodological approach adopted, the nature of the analysis, and potential constraints in the practical application of the proposed solutions. As such, the article is not a systematic review *per se*; rather, it builds upon the conclusions of previous systematic reviews by discussing and synthesizing the current state of the field. Based on this, it provides examples of practical application in EE that address the identified constraints.

The selection of reference publications could be seen as limited, as the study only presents three examples of activities designed by our research team. However, the design principles of these examples align with key aspects we consider essential in EE teaching, in relation to the study’s propositional objective. In addition, while two [63,66] of the three referenced publications include empirical validation of the activity designs with students at various educational levels, the third [17] is solely a proposal for intervention (results of its implementation will be published soon).

Furthermore, the applicability of the educational proposals recommended in the article has not been tested in diverse educational contexts. This means they may not be directly transferable to different educational systems or cultures without further modifications, which will be the subject of future studies.

Finally, although the article addresses the integration of EE and the One Health approach, it may not have thoroughly explored all possible intersections between these topics, particularly the complex relationship between technology and society in today’s technogenic world. Advances in technology have solved many health and environmental problems but have also created new challenges, such as the exacerbation of environmental degradation and health issues. This reliance on technology as a solution can sometimes discourage civic engagement and may contribute to the

limited impact of traditional EE in the classroom. These limitations underscore the need for further research to strengthen and expand upon the ideas presented.

As for the most imminent future directions, in addition to improving teachers' didactic content knowledge, to achieve meaningful behavioural change towards pro-environmental practices, it is crucial to understand the factors influencing individual decisions beyond common scientific knowledge. In this sense, several studies have identified various determinants shaping people's environmental attitudes and behaviours, including psychological, social, and cultural factors [52,86,87].

Thus, according to some authors (e.g., [86]), psychological elements, such as the perception of environmental risk and the emotional connection to nature, play a key role in whether or not pro-environmental behaviours are adopted (Eco-anger or Eco-anxiety, respectively). In addition, social factors, such as social norms and the influence of reference groups, as well as cultural differences in perceptions of nature and sustainability can also influence actions taken [52,87]. Understanding these dynamics is essential for designing effective interventions that align with the perspectives and values of different social groups.

In short, to maximize the impact of EE in promoting pro-environmental behaviours, it is important to integrate EE more effectively into school curricula (including the One Health approach), provide continuous teacher training in effective methodologies (including scientific practices), and foster intersectoral collaboration among educators, scientists, policymakers, and community leaders, in alignment with SDG 17: Partnerships for the Goals. Moreover, investing in multidisciplinary research that explores the intersection of psychology, sociology, anthropology, and education is crucial for understanding how pro-environmental behaviours are formed and sustained. If these factors are considered, teachers and educational researchers may succeed in transforming education into a genuine driver of change, rather than a contributor to the persistence of the problem.

7. Conclusions

The article provides a comprehensive overview of the current state of EE teaching and highlights the crucial role of educators in promoting sustainability and environmental justice (Figure 6). It emphasizes that the most important aspect of teaching is not the teacher's private actions, but their professional ability to foster critical thinking, empowerment/autonomy, and reflection in students about their actions and consequences. Educators must inspire students to question their environment, critically analyse socio-environmental issues, and seek innovative and sustainable solutions. This aligns with the broader educational goal of driving individual and collective responsibility, particularly when introduced in early educational stages, where values are formed, and the ability to reflect and analyse is developed.

The examples and strategies presented in this article provide useful references for teachers (practical and educational implications), enabling them to concretise the theoretical aspects of the necessary symbiosis between teaching practices in EE and Science Education. Moreover, the integration of One Health, a topic of growing relevance in the post-pandemic context, provides a powerful means of linking environmental and personal health, appealing to students' self-interest while simultaneously promoting environmental protection ("anthropocentric selfishness"). By evaluating and incorporating the principles of didactic transposition, teachers can improve their practice and adopt a more holistic and transformative approach in their classrooms. This is particularly important for teacher training programs (Figure 5), which should be reformed to emphasize these approaches, helping educators (*TeachComp*) facilitate student-driven learning experiences that reflect the real complexity of socio-environmental issues.

In terms of educational research (research implications), the article complements existing theoretical frameworks by focusing on classroom practice (which is where problem solving begins) rather than remaining confined to theoretical reflection. It advocates for the use of effective teaching strategies that promote the acquisition of environmental competencies and practical, decision-making-oriented learning. This will also lead us toward a more effective and comprehensive future evaluation of environmental education, taking into account all possible factors mentioned above

(these need to be identified and activated), leading to a better perception of the ability of these factors to modify behaviours.

As noted in the limitations section, future empirical studies could further validate these strategies by evaluating their impact on student learning outcomes in diverse educational contexts. This would help identify best practices and challenges to implementation, considering both epistemic and non-epistemic factors. Furthermore, in today's technogenic society, the integration of emerging technologies into EE, especially in the context of One Health, could open new avenues for exploring how technology can enhance collaborative and systemic learning.

Socially (social implications), this article calls for applying European scientific competency frameworks to EE, prioritizing scientific reasoning and active participation in decision-making over passive, one-way information dissemination. This approach fosters greater student engagement with socio-environmental issues and supports the development of responsible, critical citizens. By promoting an education that addresses the interconnections between health, the environment, and society, the article aims to influence public awareness and drive behavioural changes toward more sustainable, equitable, and healthy practices.

In conclusion, achieving truly TEE in thought and action requires reforming teacher training programs to strengthen teachers' didactic competences, thus impacting on classroom practice (systems thinking, scientific and epistemic practices and environmental justice awareness). Teachers should engage students in activities without clear-cut solutions, encouraging them to approach socio-environmental issues from multiple perspectives. By integrating One Health and sustainability into both teacher training and classroom practice, educators can nurture a generation of critically minded, proactive individuals, equipped to address future environmental and social challenges.

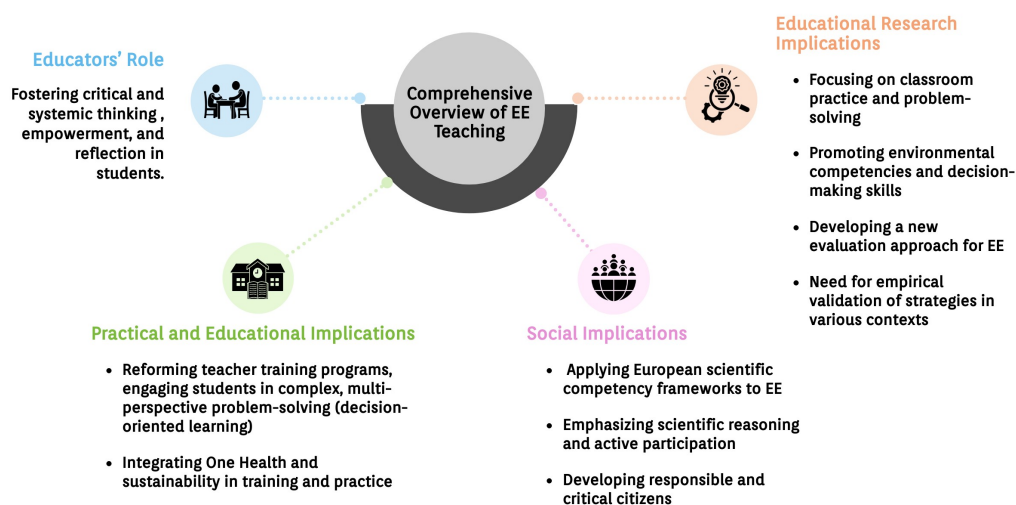


Figure 6. Implications of developing the symbiosis between EE and Science Education in educational practice, promoting a TEE that would enhance public understanding of the One Health approach.

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