

Integrating Environmental Education into Secondary-level Natural Science Curriculum for Sustainable Development: A Vietnamese Case Study

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Abstract

This study evaluates the effectiveness of integrating environmental education into secondary-level Natural Science curriculum to engage students in sustainability. Guided by Hungerford's framework, we used a deductive content analysis to examine the alignment of curriculum content across grades 6 to 9 in Vietnam. The results showed that the curriculum addresses 17 out of 19 environmental knowledge themes, covering essential topics such as biodiversity, ecosystem dynamics, and energy conservation, and emphasizes experiential learning through laboratory and field activities, enabling students to apply scientific concepts in real-world situations. However, key themes related to civic engagement, environmental ethics, and global environmental challenges are notably underrepresented. We suggest that comprehensive integration of advanced environmental education themes, including citizenship action and global issues, alongside improvements in teacher training and resource availability. Such enhancements would better prepare students for global environmental literacy and active citizenship, empowering them to contribute meaningfully to sustainable development.

Keywords: sustainable development, education for sustainable development, environmental education, environmental knowledge, vietnamese natural science curriculum

1. Introduction

Sustainable development is a central concept in development discourse, integrating "sustainable" and "development" to promote growth that meets present needs without compromising future generations' abilities to meet theirs (Mensah, 2019; Schaefer & Crane, 2005). Sustainable development emphasizes interaction with the environment in ways that prevent future resource degradation and environmental issues, including deforestation, pollution, and climate change (Abubakar, 2017; Cerin, 2006). Within this context, educating citizens, especially youth, through formal schooling is widely recognized as essential for advancing sustainable development (Bonnett, 1999) and this can be achieved through a key approach as Education for Sustainable Development (ESD) (Buckler & Creech, 2014). Over time, ESD developed as both an educational philosophy and a global movement, emphasizing two main elements: the integration of sustainability-related content and the use of participatory, reflective pedagogical methods.

ESD and Environmental Education (EE) have close relationship, however, while ESD and EE are related, they also differ in certain aspects, varying depending on regional or national perspectives. Three distinct viewpoints on the relationship between EE and ESD can be identified (Pavlova, 2011): EE is equivalent to ESD, EE is part of ESD, and EE and ESD have common but distinct elements. In Vietnam, EE is considered a part of ESD (Le et al., 2022). ESD aims to enhance awareness, skills, perspectives, and values, thereby guiding and inspiring individuals to seek sustainable livelihoods, engage in a democratic society, and act sustainably while EE places a more specific emphasis on protecting the natural environment and reducing the negative impacts of human activities. (Cecioni, 2005; Hopkins & McKeown, 2002). For Vietnam's context, EE contributes to ESD through two main approaches: (i) educating on fundamental concepts related to the environment, ecology, natural resource conservation, and climate change issues, and (ii) promoting initiatives and activities for disaster risk reduction and climate change adaptation, with a particular focus on young people.

Taking the provision and promotion of ESD as one of the five guiding perspectives in designing the new general education curriculum (Le et al., 2022), Vietnam has undertaken significant educational reforms to support sustainable development through the issuance of Resolution No. 88/2014/QH13, which led to the introduction of the 2018 General Education Curriculum that explicitly emphasizes ESD across school subjects, particularly in the social and natural science. Natural science education in Vietnam is implemented through multiple subjects and educational activities across different grade levels, including Natural and Social Sciences (Grades 1–3), Science (Grades 4–5), Natural Science (Grades 6–9), and Physics, Chemistry, and Biology (Grades 10–12). Within this system, natural science education plays a pivotal role in fostering a scientific worldview among students, encouraging objectivity, appreciation of nature, respect for natural laws, and behaviors aligned with the principles of sustainable social and environmental development.

Given the central role of natural science education in advancing EE and ESD, examining how EE is embedded within the Natural Science curriculum is particularly important. In a previous study, we analyzed the integration of EE content within the high school Biology curriculum in Vietnam (2022). However, to date, no study has systematically examined the secondary Natural Science curriculum (Grades 6–9) through an established EE analytical framework. This gap is significant, as secondary education represents a critical stage for developing foundational environmental knowledge and attitudes among students. To address this gap, this study employed Hungerford's EE framework to examine the extent to which EE is integrated into Vietnam's Natural Science curriculum at the secondary level (H. R. Hungerford et al., 1994). Hungerford's framework is widely recognized in the field of EE and has been adopted and referenced by numerous international studies (Cole, 2007; Gayford, 1996; Kim, 2003; Winther et al., 2010). Moreover, this framework was chosen because its environmental knowledge (EK) themes and subthemes align closely with both the content focus of the Natural Science curriculum and Vietnam's approach to ESD. In this study, the year themes/subthemes of Hungerford's framework were used as reference points to analyze the Vietnamese Natural Science curriculum for Grades 6 to 9, with the aim of determining the extent to which EK themes are covered.

As no previous study has examined Vietnam's Natural Science curriculum through the lens of Hungerford's EE framework, this research provides the first systematic analysis of how the curriculum aligns with this internationally recognized model. Given that 58% of Vietnamese secondary school teachers report regularly integrating EE into their teaching (Nguyen Ki Loan, 2006), this study seeks to identify strengths and areas for development to support more comprehensive and effective integration of EE within secondary natural science education in Vietnam.

Accordingly, the following research questions guide this study:

1. To what extent is EE integrated into the Vietnamese Natural Science curriculum, as analyzed through a comparison with Hungerford's EE framework?
2. How does the Vietnamese Natural Science curriculum organize learning activities to facilitate EE, and what additional activities could be feasibly implemented?

2. Methods

Deductive content analysis is a methodological approach in which data are examined using a set of predefined codes that are typically derived from prior research or an established theoretical or conceptual model (Krippendorff, 2018; McKibben et al., 2020; Vears & Gillam, 2022). In this study, the prototype EE curriculum developed by Hungerford and colleagues served as the guiding framework. Accordingly, the Vietnamese Natural Science curriculum was analyzed deductively, following the four sequential steps proposed by Krippendorff (2018): unitizing, sampling, recording, and reducing.

Step 1: Unitizing Data for Analysis

The three-year EE curriculum developed by Hungerford et al. (1994) (H. R. Hungerford et al., 1994) for students aged 10–15 years was used as the framework to identify EK themes and subthemes in the Vietnamese Natural Science curriculum. This curriculum integrates topics from chemistry, physics, and biology, and was used as the data source. Since environmental content may appear across different topics, each topic in the curriculum was defined as a unit of analysis. This allowed the data to be organized and categorized into clear, manageable units that could be systematically examined and coded according to the predefined EK themes and subthemes from the Hungerfords' framework.

Step 2: Sampling Units

This study is a small-scale study that employs purposive sampling to select only those topics from the Vietnamese Natural Science curriculum that explicitly or implicitly address environmental issues (Ahmed, 2024; Rai & Thapa, 2015). Since the units of analysis were purposively selected, the population size is small and finite. Given this finite population, we applied the adjusted Cochran's formula to determine the sample size, ensuring the precision of the results without over-sampling. Cochran's formula provides an initial estimate for large populations, which can then be adjusted for finite populations (Ahmed, 2024). Following Neuendorf's (2017) recommendation of a $\pm 5\%$ sampling error and a 95%

confidence level, the resulting sample size was considered sufficient for reliable analysis.

Step 3: Recording Categories

We defined a set of a priori binary categorical variables based on Hungerford's existing environmental framework, which includes the EK themes and subthemes. Our units of analysis, which are topics related to environmental issues, were classified into these categories using a binary coding system: a zero (indicating the category is absent from the Natural Science curriculum) or a one (indicating the category is present in the Natural Science curriculum). A codebook was developed containing all a priori categories with precise, operational definitions to minimize subjectivity. Coders applied these definitions strictly, ensuring that units were validly and reliably assigned to the appropriate categories. For convenience, we also designed coding sheets in Microsoft Excel format to facilitate the coding process.

Step 4: Reducing Units Into Categories

The reducing step mainly follows a deductive process based on the categories and definitions provided in the designed codebook. The researcher, who has been rigorously trained in content analysis, conducts a pilot test by randomly selecting 10% of the sampled units. Any confusion or inconsistency in the operational definitions of the categories is discussed thoroughly, and final codes are agreed upon. An external auditor, who is also an expert in curriculum development, is invited to objectively review the codebook, the coding sheet before reducing, and the pilot test results. During this stage, the researcher encounters a disagreement about whether categories should be defined as EK themes or EK subthemes. After examining the codebook and the pilot test findings, the external auditor recommends coding the units using EK subthemes to provide a more complete analysis of the Vietnamese Natural Science curriculum and ensure full coverage of EE content.

As in the pilot test, the main phase involves coding units one by one into the assigned categories. The coding team, which consists of four researchers, analyzes each grade independently. Then, after every 20% of the sampled units, the team meets to check interrater reliability and reach consensus on any discrepancies. Results from this deductive coding process, using numerically defined categories, are reported as frequency counts and percentages. These descriptive data show how often the a priori categories (EK themes/subthemes) appeared in the Vietnamese Natural Science curriculum.

3. Results

The results are presented in two main parts. The first part focuses on the alignment between the Vietnamese Natural Science curriculum outcomes and the EE goals. The second part examines how EK themes are spread out and covered in the Vietnamese secondary school Natural Science curriculum to see how much and in what ways environmental content is integrated.

3.1 The Alignment Between the Outcomes of the Vietnamese Natural Science Curriculum and Environmental Education Goals

Hungerford's goals for EE, articulated in his 1980 framework, are to foster an environmentally literate society capable of making informed and responsible decisions (H. Hungerford et al., 1980). These goals were modified to be consistent with the categories of objectives outlined in the Tbilisi Conference Report. They include four levels of cognitive knowledge and skills within the broad structure of environmental literacy. These goals are arranged in a hierarchical structure with four levels and twenty-four particular goal statements. The four levels are (i) The Ecological Foundations level, (ii) The Conceptual Awareness level, (iii) The Investigation and Evaluation level, and (iv) Environmental Action Skill level. The 24 components, categorized into four levels of objectives, help clarify students' expectations upon completion of the EE curriculum. Specifically, at Goal Level I, students are not only expected to understand and articulate basic ecological concepts such as ecosystems, biogeochemical cycles, and energy flow, etc., but also to apply them to analyze environmental problems, predict the ecological consequences of different solutions, and use scientific information in investigating and finding solutions to environmental and sustainable development issues. The Goal Level II aims to help students understand the relationship between humans, society, and the environment. At this level, students are expected to identify environmental problems at various scales, understand ecological and cultural consequences, consider alternative solutions, and recognize the role of beliefs, values, and civic responsibility in environmental decision-making. The Goal Level II represents a transition from ecological understanding to awareness of environmental issues within a social context. The Goal Level III requires students to participate in a systematic investigation and evaluation process. Students are able to know how to utilize primary and secondary information sources, synthesize data, and analyze problems in relation to their ecological and cultural consequences. Furthermore, this level emphasizes the ability to consider multiple solutions, evaluate the value propositions associated with each solution, and self-identify one's personal role and values in relation to environmental issues. The Goal Level IV is the highest goal, which emphasizes the role of active participation and social responsibility in addressing practical environmental issues through civic skills such as persuasion, responsible consumption, political and legal action, and ecological management. The four goal levels

represent a developmental process from forming a foundation of ecological knowledge, expanding awareness of the relationship between humans and the environment, developing investigative and assessment capabilities, to the ability to engage in practical action to address environmental issues and move towards sustainable development.

The secondary Natural Science curriculum in Vietnam is designed to develop students' scientific competence through 3 key components, including scientific knowledge, inquiry skills, and the ability to apply learned concepts to solve real-world problems. The curriculum contributes to the formation of essential student qualities and general competencies such as curiosity, scientific reasoning, confidence, honesty, and objectivity (Vietnamese Ministry of Education and Training, 2018c). It also aims to cultivate positive attitudes and responsible behaviors toward nature in alignment with sustainable development requirements. The curriculum prepares students ready to be responsible citizens and culturally aware, hard-working, and creative people who can meet their own requirements for personal growth and help the country move forward in an era of globalization and industrial transformation. These broad goals are put into action through particular learning goals that are built into every topic and lesson.

An analysis of the objectives of the Vietnamese secondary Natural Science curriculum reveals alignment with the EE's Foundation Ecology level. The curriculum outlines core ecological concepts such as organisms, populations, communities, ecosystems, biodiversity, ecological balance, and human-environment interaction, directly corresponding to the EE's foundational ecological knowledge objectives. Furthermore, the curriculum objectives require students to apply ecological concepts to analyze environmental issues, including air pollution, ecosystem degradation, and biodiversity conservation, thereby fulfilling EE's goals of ecological reasoning and sustainability analysis. At the level of environmental issue awareness, the Vietnamese Natural Science curriculum includes objectives that highlight the relationship between human activities and environmental change. Curriculum objectives repeatedly address the causes and impacts of environmental problems, the importance of environmental protection, and the role of sustainability-related practices such as pollution reduction, resource conservation, and recycling. These goals correspond with the framework's emphasis on developing awareness of human-environment interdependence and environmental problem recognition across multiple contexts.

A noticeable difference in emphasis can be seen when compared with Hungerford's Level III and IV EE goals. Although the curriculum incorporates investigative elements, such as studying ecosystem composition and examining local environmental pollution, these objectives correspond to goals at EE Investigation and Evaluation level (Level III). However, the curriculum does not extend these investigations toward systematic evaluation of alternative solutions or explicit consideration of value perspectives like the EE Goal Level III. When comparing the Level IV Goal of the EE curriculum, there is a alignment with the "applying learned knowledge and skills" competency objective of the Vietnamese Natural Science curriculum. This competency is described as "students being able to implement several solutions to protect nature; adapt to climate change; and exhibit behaviors and attitudes consistent with the requirements of sustainable development." However, the requirements of the Vietnamese Natural Science curriculum do not adequately emphasize civic action skills such as persuasion, responsible consumption, political and legal action, or ecological management.

In summary, the Vietnamese Natural Science curriculum covers goal levels I, II and III well, especially in terms of scientific knowledge, investigation, and application; however, goal level IV is not fully represented, as the program leans more towards natural science competencies than environmental action competencies as citizens. Vietnamese Natural Science curriculum is a compulsory and formal subject for all secondary students, it places greater emphasis on foundational knowledge and scientific skills, while action-oriented goals are more strongly developed in higher-level or specialized programs (Vietnamese Ministry of Education and Training, 2018c).

3.2 Environmental Education Themes in the Vietnamese Secondary School Natural Science Curriculum

This section examines the extent to which EE themes are reflected in the Vietnamese Natural Science curriculum. A content analysis was conducted to assess the degree of alignment between the curriculum's stated objectives and EK themes and those emphasized in the Hungerford's framework. The three-year EE curriculum is designed to progress from Ecological Foundations and Human as an Ecological Factor (Year 1), to Environmental Science and Environmental Health (Year 2), and finally to Problem Investigation and Citizen Action Training (Year 3). Year 1 introduces students to core ecology concepts, including ecosystems, energy flow, natural cycles, populations, communities, habitats, ... and the role of humans within ecological systems. Year 2 focuses on environmental issues related to air, water, food, waste, population growth, resource use, pollution, and human health impacts on the environment. Year 3 emphasizes investigating real environmental problems, collecting and analyzing evidence, evaluating solutions, and developing citizenship and environmental action skills. Each year curriculum is further divided into smaller EK themes. In this study, the EK themes are numbered sequentially from 1 to 26, corresponding to the EK themes across Years 1 to 3.

The content of the Vietnamese Natural Science curriculum is developed based on the integration of scientific topics: matter and its changes; living things; energy and its transformation; Earth and the sky. The topics are mainly arranged

according to a linear logic, with a certain degree of combination with a concentric structure, while also including some interdisciplinary and integrated topics to form general principles and laws of the natural world (Vietnamese Ministry of Education and Training, 2018c).

3.2.1 Year 1 & 2 Environmental Education Themes in the Vietnamese Secondary School Natural Science Curriculum

Table 1 below presents the findings on how Vietnamese secondary Natural Science curriculum corresponds to the ecological knowledges themes outlined in Hungerford's framework. The contents matching with EK themes/subthemes/indicators are shown in this table. 17 over 19 EK themes in Year 1 and Year 2 in Hungerford's framework are represented in the Natural Science curriculum. In general, 11 EK themes of Year 1 and Year 2 are covered across grades 6 to 9, except for EK 1 What is ecology? What do ecologists do?, EK 5 Ecological succession: Ecosystems change over time.

Table 1. Distribution of EK Themes in the Vietnamese secondary Natural Science curriculum across grades 6–9

Environmental Knowledge Themes	Grade Level in Vietnamese Natural Science curriculum (No. of topics)				Total	%
	6th	7th	8th	9th		
EK1 What is Ecology? What do Ecologists Do?					0	0.0%
EK2 Individuals, Populations, and Levels of Organization in Ecology	1		5		6	15.0%
EK3 The "Ecosystem Concept" Developed			5		5	12.5%
EK4 Energy and Ecosystems		1	2	1	4	10.0%
EK5 Ecological Succession: Ecosystems Change over Time					0	0.0%
EK6 Populations and Their Dynamics			3		3	7.5%
EK7 Humans As An Ecological Factor	2		4		6	15.0%
EK8 Humans Their History of Resource Consumption			1	1	2	5.0%
EK9 Soils and Allied Problems				1	1	2.5%
EK10 Water and Allied Problems			1		1	2.5%
EK11 Food Production and Hunger			2		2	5.0%
EK12 Forest Resources			1		1	2.5%
EK13 Plant and Animal Resources			1		1	2.5%
EK14 Air Pollution	1		1	1	3	7.5%
EK15 Water Pollution			1		1	2.5%
EK16 Noise Pollution		1			1	2.5%
EK17 Solid Waste Disposal			1		1	2.5%
EK18 Hazardous Waste				1	1	2.5%
EK19 Human Population Growth and Control			1		1	2.5%
Total	4	2	29	5	40	100.0%

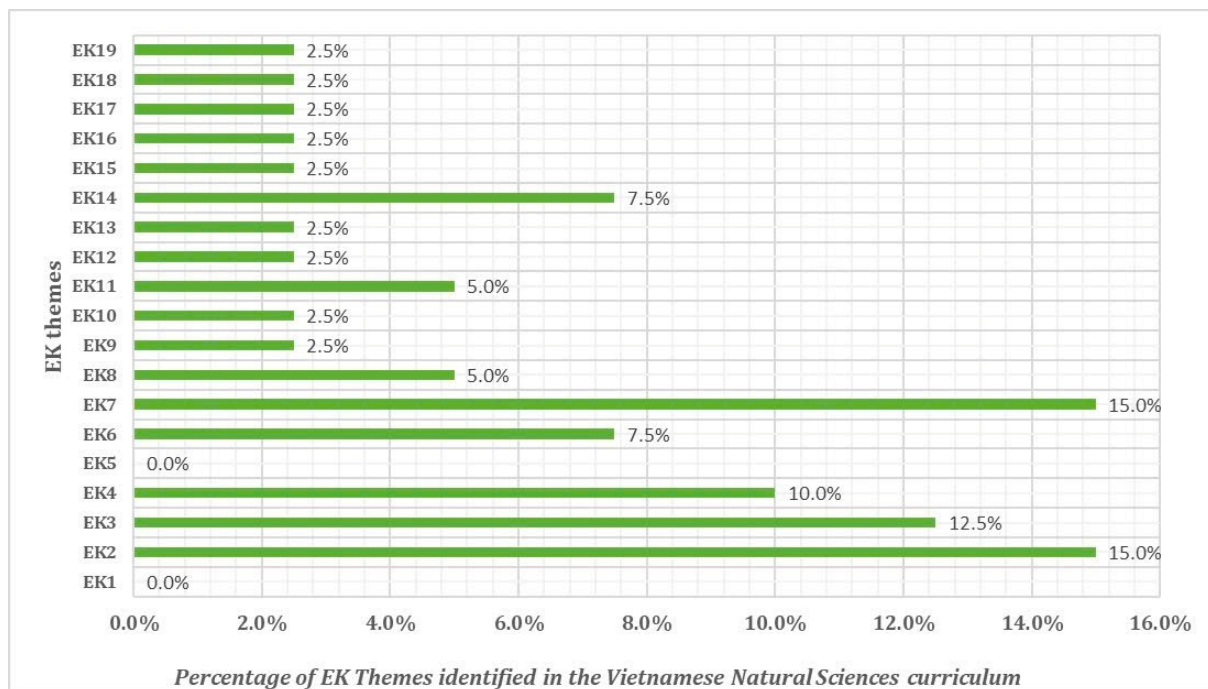


Figure 1. Percentage of EK Themes identified in the Vietnamese Natural Science curriculum

Among the 19 EK themes identified, EK2 Individuals, Populations, and Levels of Organization in Ecology and EK7 Humans as an Ecological Factor show the highest frequency, each accounting for 15% of the total occurrences. After that, EK3 The “Ecosystem Concept” Developed comes in at 12.5%, and EK4 Energy and Ecosystems at 10%. These four themes make up more than 50% of all EK-related content. This shows that there is a strong focus on basic ecological structures and direct interactions between people and the environment. Conversely, numerous EK themes manifest just superficially. EK6 Populations and Their Dynamics makes up 7.5% of the total, while EK8 Humans Their History of Resource Consumption makes up 5.0%. There are further themes like EK9 Soils and Allied Problems, EK10 Water and Allied Problems, EK12 Forest Resources, EK13 Plant and Animal Resources, EK15 Water Pollution, EK16 Noise Pollution, EK17 Solid Waste Disposal, EK18 Hazardous Waste and EK19 Human Population Growth and Control, which each show up at a low level of about 2.5%. This unequal distribution shows that some ecological and environmental issues are covered in depth while others are only briefly covered in the curriculum.

From a grade-level perspective, the distribution of EK themes is uneven. Grade 8 dominates the coverage, containing 29 out of 40 occurrences (approximately 72.5% of the total). In contrast, Grade 6 includes 4 occurrences (10%), Grade 9 includes 5 occurrences (12.5%), and Grade 7 contains only 2 occurrences (5%). This pattern indicates that environmental knowledge is heavily concentrated at a single grade level rather than being progressively distributed across grades. The detailed results for each EK theme are presented in Appendix A.

At Grade 6, the Vietnamese Natural Science curriculum integrates environmental knowledge primarily by establishing the biological foundations necessary for later ecological reasoning. EK themes at this level are embedded in topics such as cellular organization, organismal structure, and basic biodiversity, which define the individual organism as the fundamental ecological unit. Rather than addressing environmental systems explicitly, the curriculum emphasizes hierarchical biological organization (cell–organ–organ system–organism). In this way, environmental knowledge is introduced implicitly through biological structure and classification, rather than through explicit ecosystem-level analysis.

Within the Grade 7 Natural Science curriculum, the integration of environmental knowledge appears to focus on biological functions and energy-related processes. EK themes at this level are embedded within topics addressing metabolism, energy transformation, and photosynthesis, which introduce energy as a unifying principle of living systems. By emphasizing how energy is captured, transformed, and transferred within organisms, the curriculum establishes a functional bridge between organismal biology and later ecosystem-level energy flow concepts. In addition, issue-based content such as noise pollution situates environmental knowledge within human health contexts, signaling an initial shift from biological structure toward environmental impacts.

Grade 8 represents the most explicit and comprehensive integration of environmental knowledge within the Vietnamese middle school Natural Science curriculum. At this grade, multiple EK themes including populations, communities, ecosystems, biomes, the biosphere, energy flow, biogeochemical cycles, and humans as ecological factors are systematically interconnected through ecosystem-centered units. Environmental knowledge is instead organized around ecological systems, emphasizing interactions among biotic and abiotic components, material cycles, and energy transfer. The curriculum further extends this systems-based integration by situating ecological concepts within both global and local contexts. Topics such as tropical forests, aquatic ecosystems, biodiversity, wildlife conservation, and natural equilibrium are used to illustrate how human activities influence ecosystem stability. Through this approach, environmental knowledge is integrated as an analytical framework for understanding ecological relationships and human–environment interactions, rather than as isolated environmental issues.

At Grade 9, environmental knowledge is integrated primarily through applied scientific and issue-based contexts, particularly within chemistry, physics, and earth science-related topics. EK themes such as energy consumption, air pollution, hazardous waste, soil resources, and material use are embedded within discussions of fossil fuels, polymers, combustion processes, and genetic factors causing diseases. This grade-level integration emphasizes the scientific causes, mechanisms, and consequences of environmental problems, linking human activities to environmental degradation through technological and industrial processes. Unlike Grade 8, environmental knowledge at Grade 9 is addressed in a more fragmented manner, distributed across disciplinary topics rather than organized around a unifying ecological systems framework. While students are expected to understand environmental impacts and outline mitigation measures, the curriculum places greater emphasis on scientific explanation than on ecological synthesis or environmental decision-making. Consequently, environmental knowledge at this grade level functions primarily as applied scientific understanding rather than as a continuation toward integrative or action-oriented environmental competencies.

Together, the Vietnamese middle school Natural Science curriculum integrates environmental knowledge through a vertically sequenced and discipline-driven progression. Environmental concepts are introduced implicitly at Grade 6 through biological structure, strengthened functionally at Grade 7 through energy-related processes, consolidated explicitly at Grade 8 through ecosystem-based integration, and extended at Grade 9 through applied scientific and issue-based contexts.

3.2.2 Year 3 Environmental Education Themes in the Vietnamese Secondary School Natural Science Curriculum

In Year 3 of Hungerford's EE curriculum, the focus shifts to Issue Investigation and Citizenship Action Training, aiming to equip students with the skills necessary to address environmental challenges. The program's core components begin with Environmental Problem Solving (EK20), where students identify environmental issues, relevant variables, and formulate research questions for investigation (EK21). They then learn to identify and utilize secondary sources of information, process the data, and report their findings (EK22). Primary data collection follows, involving sample selection, application of sampling procedures, development and use of survey or interview instruments, conducting interviews, and systematic data collection (EK23). Subsequently, students develop data interpretation skills (EK24), organizing information into tables and graphs, drawing inferences, and formulating evidence-based recommendations. The curriculum also emphasizes independent investigation (EK25), encouraging students to select environmental issues, conduct autonomous research, and cultivate a strong sense of ownership. Finally, Citizenship Action Training (EK26) empowers students to apply diverse modes of civic engagement, enabling them to take meaningful action toward resolving environmental problems.

This comprehensive framework fosters both critical thinking and civic responsibility, preparing students to actively engage in environmental problem-solving. Designed as a progressive and hierarchical learning sequence, each stage builds intentionally upon the previous one. Year 3 directly extends the foundations established in Year 1 and Year 2. The representation of Year 3 in the Vietnamese Natural Science curriculum demonstrates a strategic integration of EE with scientific literacy. This synergy is organized through the Hungerford's EK framework, with each component reflected in specific scientific topics and practical tasks designed to foster student engagement and environmental responsibility (see Appendix B).

EK20 Environmental Problem Solving is extensively integrated across various topics in the curriculum, emphasizing human-environment interactions and the development of proactive solutions. Key examples include:

- Oxygen and Air: Students analyze air pollution issues and propose specific strategies for environmental protection.
- Energy and Energy for Life: Students evaluate energy usage in daily activities, recommend energy-saving practices, and investigate renewable energy solutions to support sustainable development.
- Sound: Students assess noise pollution and propose practical mitigation measures to protect human health.
- Metabolism and Energy Transformation: Students engage in hands-on projects promoting tree planting and forest conservation to support ecosystem sustainability.
- Resource Management (Earth's Crust and Hydrocarbons): Students explore fossil fuel use, propose strategies to reduce carbon dioxide emissions locally and globally, and suggest responsible use of energy resources such as gas, petrol, and coal.

EK21 Identifying Issues and Preparing Research Questions is inherently integrated with EK20, as effective problem-solving requires the identification of environmental issues, associated factors, and formulation of research questions.

EK22 Using Secondary Sources for Obtaining Issue Information focuses on gathering and analyzing data from existing records and literature to understand environmental challenges. Within the Vietnamese Natural Science curriculum, it is addressed through topics such as:

- Human Impact Across Social Development: Students use textual descriptions to identify environmental issues resulting from human activities.
- Environmental Pollution: Students examine illustrations and photographs to classify pollution types, understand their causes, and propose measures at home and in schools to mitigate environmental pollution.

In EK23 Using Primary Sources for Obtaining Issue Information, students actively collect firsthand data through investigative tasks, including:

- Common Materials, Fuels, and Food: Students collect and analyze data to determine material properties, evaluate environmental impacts, and propose safe, sustainable usage methods.
- Human Respiration: Students conduct local investigations on tobacco smoking and design awareness campaigns through posters.
- Exploiting Resources from the Earth's Crust: Students investigate the local impacts of climate change and global warming and recommend measures to mitigate negative environmental effects.

EK24 Interpreting Data from Environmental Issue Investigations focuses on organizing, graphing, and interpreting environmental data, developing analytical skills, and applying them to real-world environmental issue datasets. Primary and secondary data from topics in EK22 and EK23 will be further analyzed to gain a clear understanding of environmental issues.

EK25 Independent Investigation of a Student-Selected Environmental Issue requires students to conduct field research and report their findings. Examples include:

- Diversity of the Living World: Students select a local biodiversity issue, research secondary sources (books, newspapers, statistical reports), conduct primary field research using direct observation, recording, counting, and photography, employ classification tools such as dichotomous keys, and assess ecological roles of organisms. They then compile and present formal field reports.
- Environmental Protection: Students investigate specific pollution problems in their local community, collect primary data, and propose practical solutions to mitigate these issues.

4. Discussion

EE in schools can occur at various levels, including school subjects, the development of teaching materials, and initiatives to extend EE (De Haan et al., 2013). A systematic review of EE teaching practices between 2015 and 2024 confirmed that cross-disciplinary integration, alongside outdoor learning and participatory approaches, is among the most commonly documented EE practices in formal school settings worldwide. The same review noted, however, that despite this trend, widespread reliance on textbooks and teacher-centered instruction persists — a pattern that is particularly pronounced in the Global South and East Asia, where EE in schools tends to remain largely textbook-based and relatively teacher-centered (Zhang et al., 2025). In Vietnam, as in other countries such as India, Colombia, Germany,... EE is served as an integral part of the national curriculum and is taught through incorporating with existing subjects (Bolscho & Hauenschild, 2006; Ramírez Suárez et al., 2023; World Bank, 2019). Vietnam's approach of integrating EE into Natural Science subjects, rather than treating it as a standalone discipline, is therefore both globally aligned and reflective of regional pedagogical norms.

4.1 Discussion on the Coverage of Environmental Knowledge of Years 1 and 2 in the Vietnamese Natural Science Curriculum

In Years 1 and 2 of Hungerford's framework, the Vietnamese Natural Science curriculum covers substantial environmental knowledge. This is consistent with other studies suggesting that many environmental issues have high potential to be integrated into school curricula (Bolscho & Hauenschild, 2006; Ramírez Suárez et al., 2023; Witucki et al., 2018). Specifically, the curriculum addresses 17 of 19 EK themes, except for "EK 1: What is ecology? What do ecologists do?" and "EK 5: Ecological succession—how ecosystems change over time." This gap occurs because the general education system in Vietnam is divided into two stages: a basic education phase (grades 1-9) and a vocational-oriented phase (grades 10-12) (Le et al., 2022; Vietnamese Ministry of Education and Training, 2018b). During the vocational-oriented phase, students are given opportunities to select subjects that align with their abilities, interests, and future career orientations, allowing them to study selected disciplines in greater depth (Le et al., 2022). As a result, in the Grade 12 Biology curriculum, students are introduced to more specialized ecological content, including the roles and work of ecologists and ecological succession. This sequencing of ecological content across educational stages may also have important implications for EE outcomes. Research suggests that environmental knowledge positively influences environmental awareness and decision-making attitudes, highlighting the importance of systematic knowledge-building at early educational stages (Tran et al., 2022). The concentration of foundational EKs in secondary grades therefore appears strategically important, as EE has been shown to be more effective when introduced at younger ages (Hu et al., 2025). Ensuring comprehensive EK coverage in the secondary stage is therefore not only aligned with curricular design logic, but also supported by evidence on optimal timing for EE interventions.

In Vietnam's Natural Science curriculum, EKs 7, 4, 3, and 2 account for a substantially larger proportion than the other EK categories. This reflects the orientation of the secondary Natural Science curriculum, which emphasizes foundational knowledge and its connection to real-life contexts, in contrast to the upper secondary curriculum that focuses more on specialized knowledge in the basic sciences (Vietnamese Ministry of Education and Training, 2018b). In the context of EE, students are introduced to fundamental concepts in environmental ecology, particularly the application of ecological principles to practical environmental issues in their surrounding environment. This emphasis on applied, locally relevant environmental content is broadly consistent with EE best practices as EE is most effectively embedded when content is adapted to local issues and contexts, and when it extends beyond purely scientific knowledge to encompass real-world problem-solving (World Bank, 2019).

Regarding the distribution of EKs across grade levels, EKs are most frequently represented in the Grade 8 curriculum. This is consistent with the secondary curriculum structure, in which ecological content is mainly concentrated in Grade 8. Various ecological themes, including populations, communities, ecosystems, biomes, the biosphere, energy flow, biogeochemical cycles, and the role of humans as ecological factors, are systematically interconnected through units centered on ecosystems. This finding is consistent with previous comparative research between Hungerford's framework and Vietnam's 2018 high school Biology curriculum (Grades 10–12). Biology 12 covers 17 out of 19 EK themes across

different units, as ecological knowledge is primarily concentrated in the Biology 12 curriculum (Le et al., 2022; Vietnamese Ministry of Education and Training, 2018a). The concentration of EK in specific grade levels, however, raises questions about continuity and long-term retention as environmental knowledge acquired in concentrated grade-level units may diminish over time without reinforcement (Hu et al., 2025). This implies that Vietnam's Natural Science curriculum could benefit from more iterative revisiting of core ecological themes across grade levels, rather than concentrating them primarily within Grade 8.

However, strong curricular coverage alone does not guarantee effective EE outcomes in practice. The "exam-driven" nature of Vietnam's education system often causes academic subjects to outweigh EE activities, as achievement in environmental literacy is not recognized in student transcripts or university admission criteria (Quang, 2019). Furthermore, the effectiveness of these curricula depends heavily on teacher environmental literacy. Studies of Vietnamese teachers suggest their literacy is currently at a "moderate" level and needs enhancement through professional training programs to empower them to deliver the curriculum effectively (Tran et al., 2022). In low- and middle-income countries like Vietnam, targeted EE has a high potential for impact because participation is associated with a significantly larger increase in environmental knowledge and attitudes compared to developed contexts (Hu et al., 2025). This suggests that, if barriers such as resource shortages and insufficient teacher training can be addressed, the current curriculum structure may support meaningful improvements in environmental literacy.

4.2 Discussion on the Coverage of Environmental Knowledge of Year 3 in the Vietnamese Natural Science Curriculum

The integration of the Hungerford's framework into the Vietnamese Natural Science curriculum, particularly in Year 3 which emphasizes environmental issue investigation and citizenship action, represents a strategic shift toward empirical and action-oriented EE. This approach aligns with global trends that seek to move beyond the mere transmission of factual knowledge, instead fostering action competence and sustainable behaviors (Barros, 2025; Ramírez Suárez et al., 2023). Research indicates that Vietnam's EE shares similarities with programs in countries such as the United States and Colombia.

Firstly, the curriculum demonstrates a strong emphasis on interdisciplinary integration and holistic environmental problem solving. The inclusion of Environmental Problem Solving (EK20) across various scientific topics reflects a commitment to addressing authentic sustainability challenges. This finding is consistent with Environment-Based Education in the United States, where interdisciplinary planning enables students to analyze complex environmental problems from multiple disciplinary perspectives (Feinstein & Carlton, 2012). Similarly, Vietnam's Experiential Learning Activities position environmental education at the core of the curriculum by strengthening connections among geography, biology, and chemistry (Quang, 2019). To maximize the benefits of this integrated approach, learning activities should also provide opportunities for students to question, discuss, and critically reason about sustainability issues rather than simply reproducing established knowledge. Nevertheless, similar to findings from Colombia, conservation-related topics remain more prominent than broader social and economic dimensions of sustainability. In this regard, Hungerford's Year 3 framework strengthens the curriculum by explicitly emphasizing the interconnected relationships between human activities and environmental systems.

Secondly, Year 3 emphasizes data-driven inquiry and the development of empirical skills. Students advance from identifying environmental variables (EK21) to collecting and analyzing data from both secondary and primary sources (EK22, EK23). Tasks such as evaluating environmental impacts of commonly used materials or examining local climate change consequences provide hands-on, evidence-based experiences. This systematic approach to "Investigating Environmental Education Issues and Actions" aligns with U.S. models, where structured data collection and analytical activities enhance students' environmental attitudes and behaviors (Feinstein & Carlton, 2012). The focus on data interpretation (EK24) further cultivates scientific literacy and supports evidence-based recommendations, addressing a common limitation of traditional curricula, which often prioritize declarative knowledge over procedural and action-oriented skills (Barros, 2025).

Thirdly, the curriculum promotes field-based learning while highlighting contemporary challenges. Independent Investigation (EK25), including local biodiversity studies using direct observation and dichotomous keys, fosters autonomy and experiential learning. This mirrors Place-Based Education in the U.S., which leverages school-community partnerships to improve both learning and community outcomes (Feinstein & Carlton, 2012). However, rapid urbanization and increasing reliance on digital technologies limit students' engagement with natural environments, constraining outdoor fieldwork and experiential exploration (Quang, 2019). Comparable challenges in Colombia emphasize the need for enhanced teacher training and resource support to effectively implement experiential EE (Ramírez Suárez et al., 2023).

Finally, the framework highlights the transition from awareness to action. Citizenship Action Training (EK26) encourages students to engage in civic actions addressing environmental issues, a critical predictor of pro-environmental behavior (Barros, 2025). In Vietnam, EK26 content is not yet fully articulated, likely because secondary education focuses on

foundational scientific knowledge, while advanced competencies in environmental citizenship are expected in higher-level seminars and real-life projects (Le et al., 2022). Researchers also argue that integrating EE outcomes into formal assessment systems is essential for sustainability; the limited presence of such content in high-stakes examinations may reduce commitment among students, parents, and administrators, limiting broader implementation (Quang, 2019).

5. Conclusions

The Secondary Natural Science curriculum in Vietnam demonstrates a thoughtful alignment with global frameworks for ESD, particularly Hungerford's model of EE. By incorporating essential ecological concepts and practical skills, the curriculum equips students with a foundational understanding of environmental issues and the competencies needed to address these challenges. However, several areas, including advanced EE themes related to civic engagement, environmental ethics, and global environmental challenges, remain underrepresented. Addressing these gaps could further strengthen the curriculum and ensure a more comprehensive and globally informed approach to environmental education.

To maximize the curriculum's effectiveness, improvements in resource allocation, educator training, and the integration of broader global sustainability themes are recommended. Expanding EE to include stronger civic and ethical dimensions would further enhance students' capacities as informed and responsible citizens, enabling them to contribute meaningfully to both local and global sustainability efforts. With these strategic enhancements, the Natural Science curriculum can better support Vietnam's aspirations for sustainable development by fostering a generation equipped to preserve ecological integrity and contribute to a more sustainable future.

This study focused on students' understanding of existing sustainability concepts rather than examining their critical reasoning or independent evaluation of sustainability issues. Future research could investigate students' critical reasoning, systems thinking, and understanding of causal relationships among sustainability themes. It would also be valuable to extend the application of Hungerford's EE framework to the primary school Science curriculum, enabling a systematic examination of EE across the primary, lower secondary, and upper secondary levels within Vietnam's General Education Curriculum.

By providing a systematic analysis of the representation of environmental education within Vietnam's secondary Natural Science curriculum, this study offers a valuable reference for educational managers, policymakers, and other stakeholders seeking to strengthen environmental education and advance education for sustainable development in Vietnam.

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Author contributions

Dr. Thi Phuong, Le conceived the study, developed the overall research framework, designed the research methodology, supervised the project, and coordinated the manuscript preparation. Dr. Thuy Linh, Do co-developed the research framework, contributed to the study design, conducted the literature review, performed the primary data analysis, and co-drafted the manuscript. Dr. Phuong Lien Lai conducted the literature review, contributed to the data analysis, and drafted parts of the manuscript. Thi Phuong Nam Pham and Thi My Duyen Pham contributed to the data analysis and drafted parts of the manuscript. Quang Ngoc Duong and Thi Dieu Thuy Do conducted the second-round data analysis and critically revised the manuscript. Kien Huyen Nguyen critically revised the manuscript for important intellectual content. Thi Phuong Le is the first author of this study, and Thuy Linh Do is the corresponding author. All authors read and approved the final manuscript.

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