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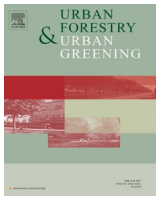

Exploring the understanding and integration of nature-based solutions into higher education and TVET: Insights from 7 EU countries

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ABSTRACT

Nature-Based Solutions (NBS) are increasingly recognised as essential approaches for addressing urban challenges such as climate change, biodiversity loss, and social resilience. One of the key factors in the successful implementation and long-term sustainability of NBS is the capacity-building role of education systems, particularly in equipping future professionals with the necessary knowledge and skills. This study explores the current understanding and integration of NBS within higher education and Technical and Vocational Education and Training (TVET) across seven EU countries: Germany, the Netherlands, Finland, Austria, Lithuania, Greece, and the Czech Republic. The research employs a mixed-methods approach, combining a review of academic and grey literature, expert interviews, and surveys. The study analyses how NBS-related content is embedded in educational curricula and training programs. The literature review reveals existing definitions and criteria for understanding NBS, while empirical findings highlight significant differences in perception, not only between countries but also across institutions. The integration of NBS in curricula remains fragmented, with limited interdisciplinary collaboration and a noticeable gap between theoretical knowledge and practical application. However, innovative formats such as Living Labs and co-creation with societal actors show strong potential to support transformative, challenge-based learning. By identifying key barriers and showcasing good practices, this study contributes to the growing discourse on educational innovation in sustainability transitions. It highlights the importance of transdisciplinary approaches and international cooperation in embedding NBS into higher education and TVET systems, and offers recommendations to support effective curriculum development.

1. Introduction

Nature-Based Solutions (NBS) have emerged as innovative, sustainable approaches to addressing complex environmental and societal challenges such as climate change mitigation and adaptation, biodiversity loss, food and water security, human health, disaster risk reduction and social and economic development (Cohen-Shacham et al., 2019; Cohen-Shacham et al., 2016). At the policy level, NBS are becoming central in the EU Biodiversity Strategy for 2030, which operationalises the biodiversity sector of the Green Deal. They are further supported by an increasing number of international and national frameworks aimed at promoting ecological resilience and socio-economic transformation (Faivre et al., 2017; Maes and Jacobs, 2017). Nature-Based Solutions are broadly understood as actions that sustainably manage, restore and conserve natural and modified ecosystems, aiming to deliver multifunctional benefits in cost-effective, resource-efficient, and context-sensitive ways (Grace et al., 2021; Raymond et al., 2017; Wanner et al., 2025). The United Nations Environment Assembly (UNEA, 2022) provides a more comprehensive definition, stating that NBS are "actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems, addressing social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience, and biodiversity benefits." This UNEA definition highlights a stronger focus on biodiversity and moves beyond the more technocratic perspectives of earlier definitions. NBS offer a holistic and adaptive approach that integrates conventional engineering with ecosystem-based practices, emphasising local adaptability and economic viability and encompasses a broad range of actions targeting cities, land- and seascapes (Nesshöver et al., 2017; Seddon et al., 2020).

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NBS are inherently complex interventions, requiring collaboration among diverse actors and integration across disciplines, institutions, and societal contexts (Croeser et al., 2021; Gómez Martín et al., 2020; Hartmann et al., 2019). By operationalising the ecosystem services concept and engaging multiple stakeholders, NBS promote transitions toward more sustainable and equitable development pathways (Raymond et al., 2023). Their effective implementation depends not only on technical knowledge but also on inclusive and transdisciplinary collaboration, stakeholder engagement, and place-based co-creation (Wickenberg, 2024; Sarkki et al., 2025). Collaborative processes bring together experts, local communities, and educational actors to co-create solutions tailored to specific contexts (Frantzeskaki, 2019; Francesconi et al., 2021). These transdisciplinary collaborations support knowledge co-production and mutual learning, demanding strong communicative, relational, and facilitation capacities (Wickenberg, 2024).

In this context, education plays a crucial role in mainstreaming NBS, though its potential remains underexplored in both practice and academic discourse (Seddon et al., 2020; Quevedo Beltrán and Sotomayor, 2023). As noted in recent EU-level policy agendas, such as the Horizon Europe Missions, the Biodiversity Strategy 2030, and the European Skills Agenda, education and training systems are expected to foster the green skills, competences, and transformative mindsets needed for implementing nature-positive solutions (EEA, 2020). Yet, despite growing research and policy discourse around NBS, their systematic integration into educational institutions remains limited and fragmented (Quevedo Beltrán and Sotomayor, 2023). To address the systemic integration of NBS in education, this study includes both Higher Education (HE) and Technical and Vocational Education and Training (TVET) institutions. While these sectors differ significantly in structure, pedagogy, and institutional capacity, both play crucial roles in fostering sustainability competencies (Brundiers et al., 2021; Wals, 2019). HE institutions often emphasise research, interdisciplinarity, and conceptual innovation, creating space for experimental approaches to NBS. TVET, in contrast, is more practice-oriented and directly aligned with labour market needs, offering untapped potential for immediate, skill-based impact in local contexts (McGrath and Ramsarup, 2024; Ehlers, 2024). However, despite the vital role of HE and TVET institutions in preparing future professionals for sustainability challenges, several barriers hinder the meaningful integration of NBS into curricula. These include conceptual ambiguity, overlap with traditional environmental topics, the risk of superficial implementation, and the persistence of siloed disciplinary structures that inhibit systemic thinking (Butt and Dimitrijević, 2022; Melanidis and Hagerman, 2022). Additionally, a lack of institutional support, educational resources, and pedagogical frameworks constrains the development of practice-oriented and context-specific approaches to teaching NBS.

To build on existing knowledge and inform future practice, this paper investigates how NBS are understood and implemented within HE and TVET programs across seven EU countries. Using a mixed-method approach, combining a literature review, expert interviews, and surveys, it identifies current practices, key enablers, and persistent challenges, and offers recommendations for advancing NBS integration into educational systems. Specifically, it addresses the following research questions:

1. What is the current understanding of NBS among educators in HE and TVET institutions?
2. How are NBS topics integrated into HE and TVET curricula in different European contexts?
3. What are the key challenges and opportunities for integrating NBS into education and training?

By shedding light on these questions, this study contributes to the growing discourse on sustainability-oriented education and aims to inform policy, institutional practice, and cross-regional cooperation, particularly in light of current European and international policy priorities.

2. Materials and methods

This study adopted a mixed-methods approach to comprehensively examine the integration of NBS into HE and TVET across seven EU countries. By combining qualitative and quantitative data collection and analysis, we aimed to capture both in-depth insights and broader patterns, thereby enabling a nuanced understanding of complex educational dynamics (Fetters et al., 2013). This methodological design facilitated a multi-perspective analysis, better addressing the diverse interests of stakeholders than a single-method approach could (Creswell, 1999). Country selection was informed by expert networks and institutional collaborations established through the EU Horizon ENABLS project, which supported efficient data collection and stakeholder engagement. The integration of both qualitative and quantitative methods further allowed for the exploration of individual and institutional perspectives alongside overarching trends within the target population.

2.1. Study design and data collection

This study explores the current understanding and integration of NBS and biodiversity within HE and TVET curricula across seven EU countries. The research followed a mixed-methods design, consisting of three key components: (1) a literature review, (2) expert interviews, and (3) surveys (Fig. 1). Building on the findings of the literature review, semi-structured expert interviews and a stakeholder survey were carried out to investigate the current integration of biodiversity and NBS in HE and TVET contexts. These qualitative and quantitative methods provided explorative insights into both the extent and the nature of NBS-related teaching practices.

- ***Literature review:*** Identifying Relevant Projects and Educational Materials and exploring the existing definitions of the NBS concept

  The initial stage of the study (February 2024) focused on mapping the existing landscape of NBS in HE and TVET. A comprehensive review of scholarly and grey literature was conducted using databases such as Scopus, Web of Science, and Google Scholar. Keywords included: “nature-based solutions” AND “education.” “NBS” AND “education,” “biodiversity” AND “higher education,” and in addition, targeted searches were carried out on platforms that provide Open Educational Resources, including CORDIS and educational repositories specialising in NBS, sustainability, and biodiversity. The aim was to identify existing teaching resources, projects, and networks relevant to integrating NBS into curricula, as well as to come up with a joint definition and understanding of NBS in the project team.
- ***Stakeholder mapping:*** Establishing the basis for interviews and surveys

  Each project partner conducted stakeholder mapping to identify potential participants for surveys and interviews. A shared coordination document was maintained on the University of Hohenheim’s Sync&Share platform to avoid duplicate contacts and facilitate structured outreach. Stakeholders were selected based on their involvement in NBS-related teaching. At BOKU University (Austria), for example, the BOKUonline platform was used to identify relevant academic staff and courses. Similar strategies were applied at partner institutions. Snowball sampling complemented this process, leveraging partners’ existing networks to broaden expert participation. The identified stakeholders include university professors, senior lecturers from universities and TVET institutions, as well as researchers at various career stages who are involved in teaching activities. Administrative staff were also engaged, including heads of departments and institutes, as well as personnel responsible for curriculum development.
- ***Expert Interviews:*** Exploring the Understanding and Integration of NBS in Higher Education and TVET Curricula

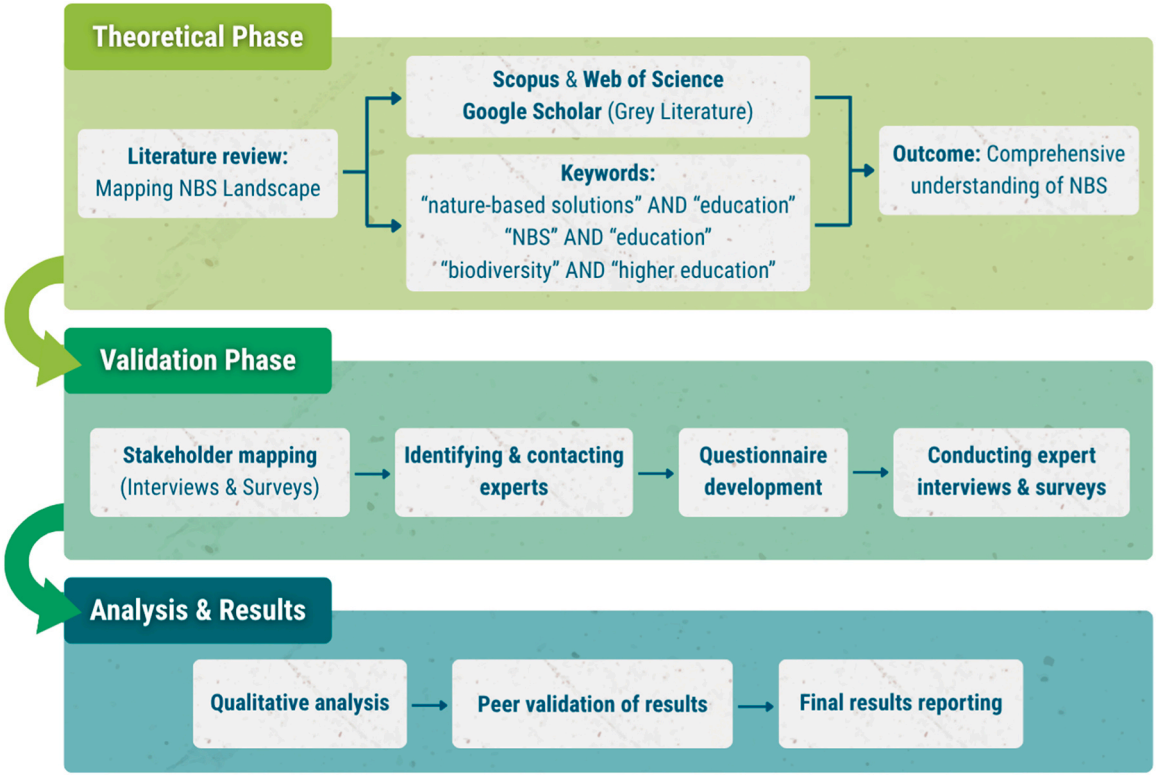

Fig. 1. Study design: Flow chart of the methodology employed in this study (Own illustration, created with Canva).

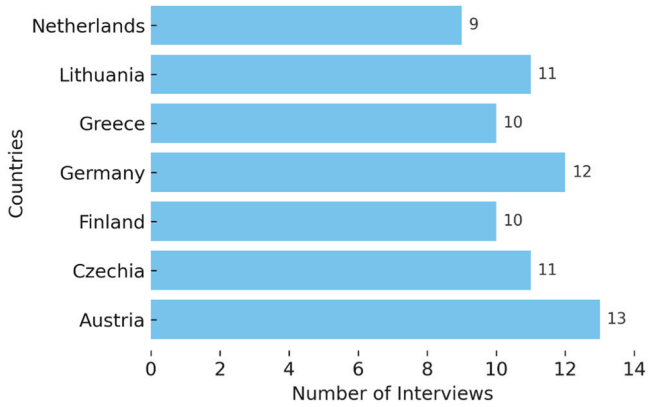

Fig. 2. Number of interviews conducted by country, own illustration (n = 76).

To complement the survey, semi-structured expert interviews were conducted to gain in-depth insights into how and why NBS topics are included in curricula.

The interviews were guided by the following research questions:

- Are NBS concepts currently integrated into HE and TVET curricula? Why or why not?
- What factors facilitate or hinder their inclusion?
- How can these topics be effectively taught?
- What improvements are needed to enhance integration?

Interview protocols were designed based on the literature review and adapted to the expertise of each respondent. Interviews were conducted between May and August 2024. In total, 76 interviews were completed within the time frame and included in this analysis.

Each interview lasted between 20 and 60 min. Responses were entered directly into the EU Survey platform. Depending on the interviewee's preferences, data were collected through direct note-taking, audio recordings (with transcripts), or a combination. Non-English interviews were translated into English by the interviewer before submission.

- ***Expert Surveys:*** Assessing Curriculum Integration of NBS

In addition to the interviews, a structured survey was developed to obtain supplementary data on the integration of NBS within HE and TVET curricula. The survey aimed to: (1) assess the extent to which NBS-related topics are embedded across various disciplines in HE and TVET institutions; (2) explore the pedagogical approaches employed in teaching NBS, and (3) identify the challenges and opportunities associated with integrating NBS into educational programs.

The questionnaire combined closed-ended (multiple choice and Likert-scale) and open-ended questions, covering the following topics:

- Demographic and institutional background
- Presence and extent of NBS content in curricula
- Pedagogical approaches and ecosystem types covered
- Future inclusion and perceived challenges

The survey was hosted on the GDPR-compliant EU Survey platform and was available from May to September 2024. It targeted University teaching staff (professors, lecturers, teaching assistants) and TVET teachers and administrative personnel. Consortium partners were responsible for distributing the survey among the experts through institutional networks, ensuring geographic and institutional outreach. Participation was voluntary and based on informed consent. All responses were anonymised, and personal data will be deleted by June 2027 per the project's data retention policy. A total of 54 valid surveys were collected from higher education and TVET institutions across 7 EU countries: Austria, Czechia, Finland, Germany, Greece, Lithuania, and the Netherlands. Of these, 38 respondents (about 70 %) were affiliated with universities, while 16 respondents (30 %) represented TVET

institutions. Participants who initially identified based on the association with the NBS and biodiversity courses came from a wide range of disciplines, such as environmental sciences, engineering, landscape planning, biology, geography, forestry, sustainability studies, and water and soil management. These respondents held various roles, including professors, researchers, deans, department heads, administrative staff, and curriculum developers.

2.2. Data analysis

The interview data were retrieved from the EU Survey platform as PDFs for analysis. ATLAS.ti 25 software was used to conduct thematic content analysis, following an inductive open-coding approach. To ensure reliability, two co-authors independently coded a subset of the data in parallel and then compared their coding schemes. Differences were discussed and resolved through consensus, which led to the refinement of the coding framework. This process helped to validate the codes and improve consistency in interpretation. Following coding, the data were grouped into thematic dimensions. These dimensions reflected the main areas of the research and helped guide the interpretation of results based on the research questions (Flick et al., 2004; Maxwell and Chmiel, 2014).

The survey data were downloaded from the EU Survey platform for thematic analysis to identify the current state of the NBS integration into the HE and TVET curriculum, specific courses, disciplines, etc. The obtained results were integrated with the other data collected in order to answer the stated research questions.

3. Results

3.1. Understanding of Nature-Based Solutions in Higher and Vocational Education: Insights from Literature and Policy Review

Based on the literature review and a thorough discussion of project partners, the following criteria were identified to define the concept of NBS and guide further empirical data collection.

NBS encompass a wide range of strategies, including ecosystem restoration, ecosystem protection, blue-green infrastructure, and ecosystem-based disaster risk reduction (Seddon et al., 2020; Wanner et al., 2025). These approaches are instrumental in enhancing ecosystem services, supporting biodiversity conservation, mitigating climate change, and promoting community well-being (IUCN, 2016). The implementation of NBS delivers multiple co-benefits across environmental, social, and economic dimensions. Environmentally, NBS contribute to climate resilience through carbon sequestration, temperature regulation, and improved water management, achieved via wetland restoration and watershed management (Sowińska-Świerkosz & García, 2022). They also play a critical role in conserving biodiversity by protecting and regenerating habitats (Bianciardi et al., 2023). In urban contexts, NBS support sustainable development by integrating green infrastructure, which enhances air quality, reduces pollution, and strengthens urban ecosystems (Butt and Dimitrijević, 2022). From a social perspective, NBS improve quality of life by fostering interactions with nature, offering recreational spaces, and promoting community engagement (Skodra et al., 2020). Their role in disaster risk reduction is also notable, providing natural defences against floods, landslides, and wildfires (Hartmann et al., 2019). Economically, NBS can generate employment in green sectors, reduce the costs of built infrastructure, and enhance financial resilience by leveraging ecosystem-based solutions. Table 1 below illustrates the definition and examples of NBS:

Table 1
Overview of Nature-Based Solution Types and Their Application Contexts. Own illustration, based on (Bianciardi et al., 2023; IUCN, 2016; Jones et al., 2024; Seddon et al., 2020; Rizzo, et al., 2020; Sowińska-Świerkosz and García, 2022).

NBS Type	Definition	Selected Examples
Ecosystem Restoration	Recovery or enhancement of degraded ecosystems to improve ecological integrity and the delivery of ecosystem services such as carbon sequestration, water purification, and biodiversity support.	• Reforestation of degraded landscapes • Wetland restoration for water quality and biodiversity • Coral reef regeneration and fishery revitalisation • Rewilding with keystone species
Ecosystem Protection	Conservation of intact or semi-natural areas to safeguard biodiversity, ecosystem services, and cultural values. Emphasizes proactive preservation to maintain ecological functionality.	• Protected area designation and wilderness preservation • Peatland conservation for climate mitigation • Indigenous land stewardship systems • Community-based conservation initiatives
Blue-Green Infrastructure & Sustainable Urban Design	Integration of natural elements into urban planning to enhance human well-being and ecological resilience. Focuses on multifunctional spaces that address both biodiversity and societal needs.	• Green roofs and walls to reduce urban heat • Permeable pavements for sustainable drainage • Green corridors to support urban biodiversity • Community gardens for well-being and cohesion • Constructed Wetlands and Treatment Wetlands
Ecosystem-Based Adaptation & Ecosystem Disaster Risk Reduction (Eco-DRR)	Use of ecosystem services to reduce climate-related and geophysical risks. Builds on conservation/restoration to enhance resilience and integrate nature into disaster risk strategies.	• Mangrove and coastal wetland restoration for storm protection • Agroforestry and sustainable land management • Ecosystem-based fisheries for food security • Integrated water resources and watershed management • Use of natural barriers (e.g. reefs, forests) for flood and landslide mitigation • Incorporation of traditional knowledge in risk reduction

3.1.1. Exclusion criteria for NBS

To assess the effectiveness of NBS is essential to apply multidimensional criteria that extend beyond ecological benefits to include governance, management, and socio-economic considerations (Davids et al., 2024). Effective NBS require inclusive stakeholder participation, adaptability to local ecological and socio-economic contexts, and cost-effectiveness, thereby ensuring that the benefits delivered outweigh the financial and resource investments (Skodra et al., 2020). Furthermore, successful NBS must enhance ecosystem services, including biodiversity, soil health, water management, and air quality, while incorporating flexible and adaptive management strategies responsive to evolving data and climate conditions (Bianciardi et al., 2023; Seddon et al., 2020). To differentiate NBS from other interventions, Sowińska-Świerkosz and García (2022) identify a set of exclusion criteria. These include actions that lack ecosystem integration, merely mimic natural forms without ecological benefit, or are implemented without addressing clearly defined challenges. Additionally, projects that harm biodiversity, replicate the functions of grey infrastructure without added value, or result in unequal distribution of benefits do not align with the principles of NBS. Community engagement and transparency are fundamental; therefore, top-down approaches and solutions lacking stakeholder involvement or local adaptation are excluded from NBS classification (Wickenberg, 2024). Table 2 outlines key criteria and

examples of interventions that do not meet the definition of Nature-Based Solutions.

3.2. Understanding of NBS in higher and vocational education: perceptions from academic and training professionals

Despite a literature-based understanding of NBS, the interviews and surveys conducted across Austria, Czechia, Finland, Germany, Greece, Lithuania, and the Netherlands reveal a highly diverse understanding of NBS within higher education and TVET. Table 3 provides an overview of the aggregated results on how NBS are understood and integrated into university and TVET curricula.

In Austria, the perception of NBS varied widely. Most of the educators were familiar with EU policy definitions and practical implementations such as green roofs, facade greening, and ecological design. This conceptual gap was particularly pronounced among those whose work focuses on broader themes like sustainability or biodiversity without direct exposure to EU discourse. However, even when the term was not used, educators described initiatives such as urban green spaces to mitigate climate change that align closely with NBS principles. However, concerns about greenwashing and vague definitions were also raised, suggesting scepticism about the term's practical relevance.

Finland presented a moderate familiarity with NBS. Educators frequently referenced biodiversity, circular economy, and the broader green transition. There was a shared understanding that NBS includes solutions benefiting both people and ecosystems, such as actions that enhance sustainability while respecting ecological limits. However, even in Finland, not all participants were entirely clear on the terminology itself, indicating that while the conceptual foundations of NBS are present, its visibility as a defined term is still emerging.

Czech respondents generally lacked familiarity with the term altogether. Most associated NBS are only indirectly associated with blue-green infrastructure or ecosystem-based thinking. Unlike in Finland, where educators often connected NBS to ecosystem services or climate resilience, the Czech context showed a more limited understanding. This suggests that the foundational principles of NBS might be understood implicitly, but the formal terminology and its policy relevance have not been internalised within educational settings.

In Germany, the term was also not widely recognised, particularly within the TVET sector. When mentioned, NBS was often associated with technical practices like biotechnology, pest control, recycling, and urban climate adaptation strategies. Educators tended to focus on practical, often product-oriented measures, with less emphasis on NBS as a holistic or policy-guided approach. In Germany, NBS was largely understood as a tool to address urban challenges, rather than a concept embedded in educational philosophy or planning.

Greece revealed an engineering-oriented interpretation of NBS, with references to carbon farming and mimicking natural systems in built

Table 2
Exclusion criteria of NBS. Own illustration, based on (Biancardi et al., 2023; IUCN, 2016; Jones et al., 2024; Seddon et al., 2020; Sowińska-Świerkosz and García, 2022).

Exclusion Category	Definition	Examples
No ecosystem integration	To be recognised as NBS, interventions must incorporate or improve ecosystems and biodiversity. This excludes activities such as harnessing wind, waves, or solar energy.	Solar panels, wind farms, and wave energy systems without ecological restoration
Biomimicry	Copies nature's designs and processes to produce novel ways of enhancing resilience, but it is not an NBS unless it is used to improve ecosystems and biodiversity.	Buildings inspired by termite mounds for cooling without enhancing local biodiversity
Random interventions	NBS must be deliberate, with defined goals and structured management. Mimicking nature without ecosystem benefit (e.g., artistic installations) is excluded.	Artistic green sculptures or vertical gardens without ecosystem service contribution
Post-implementation goals	NBS must address pre-identified problems. Historical blue/green infrastructure may not qualify unless modernised for today's ecological needs.	Old urban parks not adapted to current biodiversity or climate challenges
Negative / no impact on biodiversity	NBS must enhance biodiversity. Actions that do not or harm it are excluded.	Monoculture tree plantations, invasive species planting
Same benefits as grey infrastructure	NBS should add value beyond grey infrastructure. If not, they're excluded.	Green roofs without added ecosystem services or social benefits
Unfair benefit distribution	NBS must benefit both nature and society. Excludes actions without consent or engagement of local communities.	Projects imposed without local input or that benefit only one group
Ineffective or inefficient solutions	NBS must be cost-effective, adaptive, and context-specific.	Imported planting schemes with high maintenance and low survival rates
Top-down model of governance	NBS must involve transparent, participatory planning.	Government-led projects excluding local communities from decision-making
Static management approach	NBS must allow for adaptive management and stakeholder feedback.	Set-it-and-forget-it greening initiatives without ongoing evaluation
Unbalanced costs and benefits	NBS must provide good value. High cost/low benefit options are excluded.	Urban installations needing frequent replanting without ecological return
Microscale approach	NBS should consider wider system benefits and impacts.	Pocket parks implemented without connection to broader urban planning

Table 3
Cross-Country understanding of NBS and Curricula Integration based on interview and survey results (own illustration, n = 130).

Country	Understanding of NBS	Integration into Curricula	Description
Austria	Moderate	Partial	Fragmented awareness; some alignment with EU definitions; strong bottom-up initiatives and examples in green building.
Czechia	Low	Minimal	The term is largely unknown; minor appearances in technical courses without strategic integration.
Finland	Moderate	High	Conceptual grounding is present; biodiversity and green transition are mainstreamed through electives and sustainability programs.
Germany	Low-Moderate	Moderate	TVET focuses on technical elements; universities offer NBS-related content, but framing is inconsistent.
Greece	Moderate	Broad	Strong interdisciplinary approaches; cultural and traditional dimensions enrich NBS implementation.
Lithuania	Low-Moderate	Moderate	Sustainability themes present without precise terminology; emphasis on ecological and forestry practices.
Netherlands	High	Advanced	Clear conceptual foundation; robust integration into both theory and practice; pedagogical innovation evident.

environments. Although familiarity with the term varied, the associated discourses were rich and included environmental education, corporate social responsibility, and sustainable food systems. Greek educators emphasised the integration of environmental awareness, local community engagement, and traditional knowledge, suggesting a cultural dimension to NBS that was less prominent in the northern and central European countries. This broader framing shares similarities with Dutch interpretations, though the Dutch responses reflected deeper conceptual integration and more advanced vocabulary tied to ecological and regenerative practices.

In Lithuania, most respondents claimed to understand NBS, but their descriptions often lacked depth or clarity. The term was generally equated with environmentally friendly or sustainable actions without clear differentiation from general ecological measures. Although the intention to benefit both nature and people was frequently cited, it was difficult for participants to identify comparable or overlapping concepts.

Among the seven countries, the respondents from the Netherlands demonstrated the most comprehensive understanding of NBS. Dutch educators consistently described NBS as nature-based interventions that enhance ecosystem resilience, solve societal problems, and support climate mitigation and biodiversity. Dutch respondents embraced a wide range of related practices, such as ecological engineering, coastal protection, agroecology, and regenerative agriculture.

3.3. Integration of the NBS into the HE and TVET curricula

3.3.1. Current practices of NBS integration in education

Across the seven studied EU countries, there is growing awareness of the importance of NBS in education. However, how they are included in study programs varies widely. NBS topics can be found in many different fields, such as landscape architecture, biology, ecology, social sciences, education, and design, showing their broad, interdisciplinary nature. These topics are mostly taught at the Bachelor's and Master's levels, while they appear less often in TVET or non-degree programs.

Austria shows partial and fragmented integration of NBS. Institutions such as BOKU University offer seminars on green building and circular economy within environmental and agricultural sciences, yet system-wide uptake remains limited. At the Technical University (TU) Vienna and other universities, NBS-related content tends to be project-based or extracurricular, reducing its visibility in core curricula. In Czechia, integration is minimal. NBS themes appear occasionally in urban engineering courses, but there is little evidence of institutional strategies to embed them across programs. The concept is often underdeveloped or addressed only indirectly. Finland presents a more favourable environment for NBS education, particularly in biology, ecology, and environmental sciences. Although the integration often relies on individual instructors and elective courses, subjects such as Changing Vegetation (University of Helsinki) provide hands-on field-based learning that prepares students for real-world environmental challenges. Germany demonstrates more institutionalised integration. Programs in landscape ecology, ecosystem services, and environmental planning often incorporate NBS principles, even when not explicitly labelled as such. Courses related to urban greening and resilience planning reflect national policy trends, though inconsistency in terminology persists. Greece offers a holistic and interdisciplinary interpretation of NBS. Courses in natural resource economics, sustainability, and environmental ethics are complemented by modules in ecotourism, citizen engagement, and even ecofeminism education. These diverse entry points illustrate a creative and context-sensitive curriculum design. In Lithuania, NBS-related content is embedded within established environmental science and sustainability programs. Topics such as Nature Management, Ecological Farming, and Aquatic Biology reflect foundational NBS principles. Practical conservation activities and green logistics further reinforce experiential learning, despite limited use of NBS-specific terminology. The Netherlands stands out for its experiential, pedagogically innovative integration. Programs cover ecosystem functioning, soil health, agroecology, and water management NBS approaches. Field visits, real-world models, and guest lectures enhance student engagement. Progressive teaching models such as wild pedagogies and action learning further support a deepened understanding of NBS, although integration in vocational fields such as para-veterinary training is still limited.

Across countries, NBS modules frequently draw on frameworks such as the Ecosystem Approach, Ecological Engineering, and Blue/Green Infrastructure. Thematic overlaps include biodiversity conservation, climate adaptation, and sustainable land and water management. While some programs give NBS a central role, others address it tangentially, embedding content within broader themes like biodiversity, conservation, and ecosystem health. Educational programs are often categorised under agriculture, forestry, fisheries, and veterinary studies, but also extend into social sciences, arts, humanities, and even health-related disciplines. This reflects the interdisciplinary nature of NBS and its potential to bridge ecological and societal dimensions in education.

3.3.2. A comparative view of NBS integration in HE and TVET

Both university and TVET programs contribute to building sustainability competencies, but they integrate NBS differently, reflecting their respective emphases on theory and practice. TVET programs are hands-on and industry-specific, focusing on fields like construction, forestry, agriculture, water management, and environmental education. These programs emphasise local ecosystem management and conservation. For example, the Waldpädagogik - Biodiversität module at Forstliche Ausbildungsstätte Traunkirchen (Austria) provides practical training in biodiversity and forest conservation. At the Karalius Mindaugas Vocational Centre (Lithuania), animal care training includes ecological engineering and ecosystem-based approaches through green infrastructure components. In contrast, university programs adopt a broader, research-oriented, and interdisciplinary perspective. They address global sustainability challenges and link NBS to urban planning, ecosystem services, and climate adaptation. The Master of Engineering in Sustainability Management at Karelia University of Applied Sciences (Finland), for instance, explores global climate impacts and strategic NBS application in urban and regional planning.

University programs generally cover a broader range of ecosystems, such as terrestrial, aquatic, and urban and offer more theoretical and interdisciplinary perspectives. TVET programs, while more practice-oriented, also address diverse ecosystems, including urban and peri-urban areas, through modules focused on applied skills in fields such as forestry, agriculture, and construction. Both types of programs play complementary roles in preparing learners to implement NBS in varied ecological and socio-economic contexts. These differences also appear in course structure and credit allocation. TVET programs offer short, skill-based modules with lower ECTS credits, such as Greece's Green Skills for the Unemployed program (Apopsi), which emphasises circular economy and sustainable resource management. University programs, by contrast, offer in-depth modules with higher ECTS credits, often incorporating research and inter- and transdisciplinary elements. For example, the Karelia University program assigns 10 ECTS credits to the course Change Agency for Sustainability, which explores NBS implementation in global climate contexts. While TVET programs include applied areas such as local biodiversity conservation and sustainable land use, university programs adopt a broader perspective, exploring global ecosystem challenges and the role of NBS in addressing them.

3.4. Challenges and opportunities for embedding NBS in education and training

This chapter outlines key barriers and enablers for integrating NBS into education, with implications for policy and institutional practice.

3.4.1. Challenges in embedding NBS in higher and vocational education systems

- *Institutional and Curricular Constraints*

Inflexible institutional structures and traditional, overloaded curricula hinder NBS integration, especially in Greece and Finland, where legislation limits TVET flexibility. Financial constraints in Czechia, Finland, and Germany restrict course expansion, interdisciplinary teaching, and practical activities essential for NBS learning.

- *Limited Awareness and Conceptual Ambiguity*

Fragmented understanding and lack of shared definitions weaken NBS visibility, as seen in Austria and Greece, where it is subsumed under broader environmental topics. This ambiguity leads to inconsistent teaching and challenges in TVET due to the abstract nature of NBS.

- *Narrow Teaching Focus*

Programs often emphasise technical infrastructure over social and ecological aspects. Austrian, German, and Dutch respondents note the need to overcome single-discipline approaches and incorporate transdisciplinary perspectives.

- *Lack of Practical Implementation and Pedagogical Innovation*

There is a widespread demand for hands-on learning, such as fieldwork, excursions, and visual tools, yet funding, time, and trained staff shortages, especially in Finland and Greece, limit such opportunities.

- *Resource and Staff Limitations*

Common barriers include a lack of trained educators, funding, and institutional support. Motivated teachers often incorporate NBS in their free time, but systematic backing, such as training and co-teaching models, remains scarce, particularly outside environmental departments.

3.4.2. Opportunities for embedding NBS in higher and vocational education systems

- *Interdisciplinary and Transdisciplinary Education*
  Strong interest exists in integrated learning through joint teaching activities by integrating the stakeholders outside of academia, as advocated in Austria, Germany, and the Netherlands, linking social sciences, ecology, engineering, and planning.
- *Real-World and Local/Regional Relevance*
  Aligning NBS education with local challenges, such as flood prevention and biodiversity, strengthens relevance, especially in TVET. Dutch and Finnish interviewees recommend closer ties between curricula and regional sustainability efforts.
- *Innovative and Experiential Pedagogies*
  Pedagogical innovation, including AR/VR, place-based learning, and student-led fieldwork, can enhance engagement. The Dutch concept of "Natural Intelligence" emphasises nature as a co-educator, enriching emotional and ethical learning dimensions.
- *Motivated Educators and Bottom-Up Initiatives*
  Personal commitment from educators, even outside traditional sustainability fields, is a key asset. Investment in training, peer networks, and capacity building supports course redesign and integration of NBS.
- *International Collaboration*

Learning from global best practices and fostering transnational partnerships across universities, research institutions, and local stakeholders strengthens NBS education by grounding it in diverse real-world contexts and encouraging knowledge exchange.

4. Discussion

This study examined how NBS are understood and integrated into higher education and TVET across seven EU countries. It investigates: (1) the current understanding of NBS in universities and TVET; (2) the integration of NBS into HE and TVET curricula; and (3) the main challenges and opportunities for embedding NBS in education and training.

4.1. Understanding NBS: between familiar ideas and new approaches

In line with previous studies (Kabisch et al., 2016; Raymond et al., 2017), our findings show that while awareness of NBS is growing, its interpretation, terminology, and application in education remain inconsistent. NBS is still a relatively new concept in teaching but builds on earlier ideas such as ecosystem-based approaches, green infrastructure, and ecological engineering. Although many educators recognise the core idea of using nature to address societal challenges, few are familiar with broader policy dimensions like stakeholder co-creation, multifunctionality, or links to climate and biodiversity goals. NBS is often associated with sustainability education, especially in environmental disciplines, but is interpreted and taught differently across Europe. Without clearer guidance and support, a consistent shift in NBS education is unlikely.

Our findings support the framing of NBS as a "boundary concept" (Frantzeskaki et al., 2019; Wickenberg, 2024), capable of connecting diverse sectors but also causing confusion due to its broad and evolving meaning. This ambiguity is especially apparent in TVET and non-environmental academic fields. Similarly, a study on French Master's programs reveals that while NBS concepts are emerging, their integration into curricula remains limited, emphasising the need for formal education to incorporate more adaptation strategies (Versini et al., 2023). Evidence from Latin America illustrates potential ways to address such ambiguity: Valdes et al. (2025) show that linking NBS with sustainable construction in engineering education, through clusters such as green project management, sustainable materials, and bioengineering, helps to clarify competencies and expected outcomes.

A key insight from our study is the gap between teaching that explicitly uses the term "NBS" and teaching related topics, like urban greening or biodiversity restoration, without labelling them as such. Educators often rely on overlapping terms shaped by cultural and linguistic contexts. While EU policy promotes a common approach, local knowledge systems and academic traditions continue to shape how NBS and sustainability are taught. Acknowledging this complexity is essential for advancing NBS in education and training. Similar findings are reported outside Europe, for example in Latin America, where NBS teaching has likewise emerged from related traditions such as ecological engineering and green infrastructure, but with a particularly strong emphasis on water-related solutions, including constructed wetlands and biofilters, reflecting regional priorities in wastewater management and urban water challenges (Contreras et al., 2022; Vera-Puerto et al., 2024).

4.2. Integration into curricula: fragmentation and emerging practices

Despite a growing number of EU-funded projects and policy initiatives for integrating NBS into education, our findings show that curricular integration remains fragmented and inconsistent across countries and education levels. NBS is more common in higher education, especially Master's programs in environmental science or sustainability, while its presence in TVET is limited and often informal. This pattern of limited, often elective, or higher-level implementation is echoed by studies in Central Europe: in Croatia, Czechia, and Slovenia, NbS content is present in relatively few courses, mainly at master's or doctoral level,

and only a small number of compulsory offerings exist (Potočki et al., 2023). This reflects a broader trend in sustainability education, where universities have taken the lead in curriculum innovation (van der Wee et al., 2024), whereas TVET often lags due to structural and institutional constraints (McGrath and Ramsarup, 2024). However, the limited integration of NBS in TVET is particularly concerning, as this sector is well-positioned to support NBS implementation in urban and peri-urban areas due to its practical focus and strong community connections. While some TVET programs, such as those in forestry, construction, or land management, engage with NBS-related content, these efforts are rarely aligned with the broader NBS policy discourse or embedded in strategic governance frameworks (Stijnen et al., 2024). Strengthening TVET's contribution to NBS education will require targeted measures, including the development of dedicated learning outcomes, teacher training initiatives, and the formal integration of NBS into national qualification frameworks (OECD, 2023).

Our findings show that NBS integration tends to focus on urban contexts, which are key areas of biodiversity loss, climate vulnerability, and social inequality. Embedding NBS into education can equip learners with the knowledge and skills to foster resilience and sustainable urban development, aligning with EU policy priorities and global frameworks (EEA, 2020). Comparing TVET and university programs reveals their complementary contributions to NBS education. TVET offers practical, place-based training aligned with local ecosystems and needs, building hands-on skills for sectors like construction, forestry, and environmental management, as highlighted by McGrath and Ramsarup (2024). In contrast, universities provide broader theoretical and interdisciplinary foundations, equipping students to tackle complex sustainability challenges and engage in research and policy at national and international levels (Wiek et al., 2011).

This study highlights three main ways NBS are currently integrated into curricula: (1) full integration into core courses and modules; (2) partial or elective inclusion; and (3) peripheral incorporation through extracurricular activities or isolated project work. This typology helps assess institutional readiness and guide future curriculum and policy development. Recent empirical cases provide concrete models of how dedicated NBS courses or integrated programmes can be designed. For example, Vera-Puerto et al. (2024) present a course proposal in which course learning outcomes and competencies were defined via Developing a Curriculum Methods, targeted at a mixed cohort of undergraduates, postgraduates, professionals and educators, and evaluated for satisfaction and professional applicability. Although some institutions, particularly in Finland and the Netherlands, have implemented innovative, inter- and transdisciplinary approaches like living labs and challenge-based learning, such examples remain limited (van der Wee et al., 2024; Soini et al., 2023). Expanding these practices will require targeted investment and stronger coordination between higher education and vocational systems (Ehlers, 2024). Comparative evidence from Latin America highlights a similar fragmentation, but also shows that short professional courses and training often play a more prominent role in NBS education by directly linking to on-the-ground applications, particularly in water and sanitation contexts (Vera-Puerto et al., 2024).

Building on these insights and based on our empirical findings, we propose a conceptual framework that illustrates a stepwise process for effectively embedding NBS into higher education and TVET curricula (Fig. 3). This framework synthesises the results of this study and lessons from practice across the seven EU countries examined. It highlights how institutions can move from fragmented or pilot-based initiatives toward systematic and long-term integration. The process begins with a systematic review of existing curricula and institutional priorities, followed by mapping current NBS-related content, engaging stakeholders in co-creation, and piloting approaches with motivated educators. Continuous feedback and iterative improvement enable refinement and scaling, leading to the institutionalisation of NBS in curricula, teacher training, and accreditation processes. This cycle reflects a dynamic, collaborative, and evidence-informed pathway that supports universities and TVET institutions in aligning NBS education with sustainability goals and regional needs.

4.3. *Barriers and enablers: the role of institutional and organisational contexts*

A central goal of this study was to explore the barriers and enablers for integrating NBS into higher education and TVET. Echoing previous

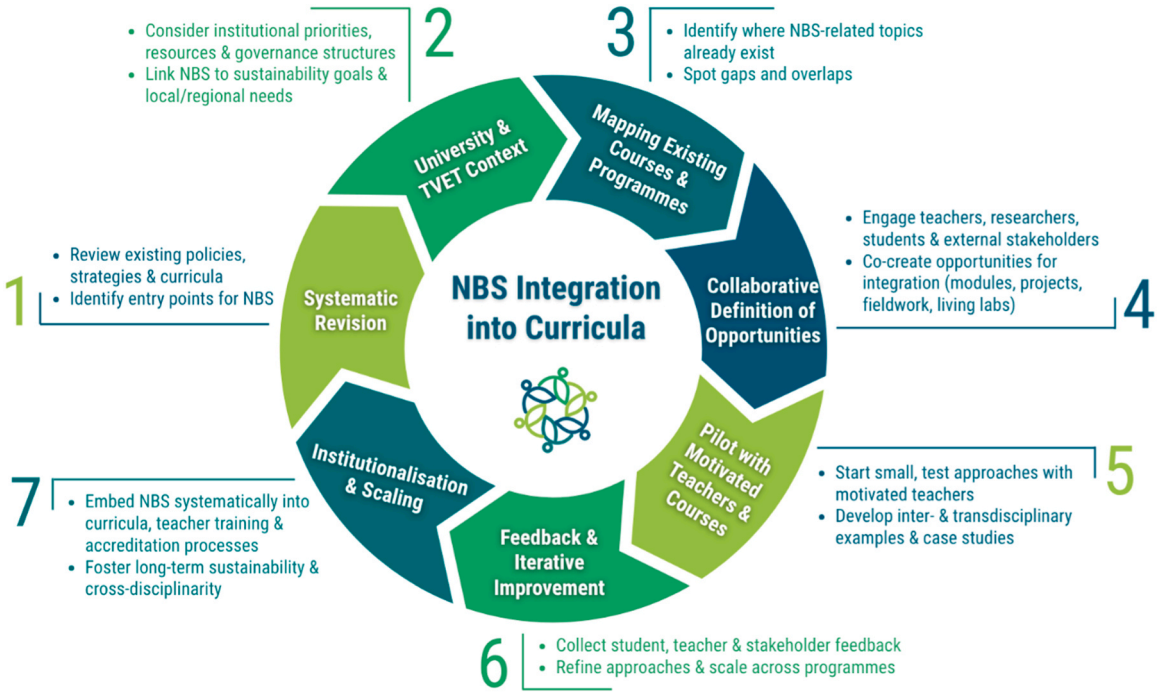

Fig. 3. NBS integration into curricula: A stepwise framework for embedding Nature-Based Solutions in higher education and TVET (Own illustration, created with Canva).

research (Nesshöver et al., 2017; Stijnen et al., 2024), we found that low awareness, conceptual ambiguity, siloed disciplines, and limited funding remain key challenges. Our findings further reveal that institutional fragmentation, inflexible curricula, and limited interdisciplinary structures hinder NBS integration. These barriers differ by context: HE institutions often struggle with overcrowded classrooms and limited experiential learning, while TVET institutions face national curriculum constraints and gaps in teacher training on NBS themes. Such differences highlight the need for context-specific, system-wide strategies. As Wals (2019) argue, sustainability education requires institutional transformation, not just curriculum reform. Similarly, Macintyre et al. (2024) call for whole-institution approaches that embed sustainability across governance, teaching, and community engagement.

Despite these challenges, several enablers emerged. Motivated educators, supportive leadership, and alignment with local environmental issues (e.g., heat stress, biodiversity loss) facilitate NBS integration. These align with broader literature emphasising the importance of agency, collaborative culture, and institutional vision (Butt and Dimitrijević, 2022; Mahmoud et al., 2022). In the NBS context, co-creation, stakeholder engagement, and integration of policy frameworks, such as the EU Green Deal or local adaptation plans, help connect learning to real-world applications (Davids et al., 2024). Rising student interest in applied and challenge-based learning also plays a key enabling role. NBS offers an effective starting point for transdisciplinary education that builds sustainability competencies and civic engagement (Brundiers et al., 2021). However, scaling such practices requires institutional support through staff development, policy alignment, and stakeholder integration. Finally, embedding NBS into education must move beyond individual initiative toward a coordinated, systemic approach. This aligns with experiences reported in Latin America, where scholars emphasise the need for specialist training and institutional support to overcome skill shortages and mainstream NBS into education systems (Contreras et al., 2022). Aligning curricula with broader Sustainable Development Goals at the institutional and national levels is essential to equip future professionals with the skills needed to design and implement effective NBS (Acharya et al., 2020; Mahmoud et al., 2022).

4.4. Linking NBS with EU educational and policy agendas

Integrating NBS into education demands institutional innovation and alignment with European policy priorities such as the EU Biodiversity Strategy 2030, Horizon Europe's Mission on Climate-Neutral and Smart Cities, the New European Bauhaus, and the European Skills Agenda. These frameworks emphasise the vital role of education in equipping learners with the skills, knowledge, and values needed to support green transitions and implement nature-positive solutions across sectors. However, our findings suggest a persistent gap between policy aspirations and educational practice. While research-intensive universities are increasingly integrating NBS through inter- and transdisciplinary modules and projects, vocational education still shows limited engagement. This disconnect reflects broader challenges noted in recent scholarly literature, which stresses the need for closer coordination between educational systems and environmental governance (Kabisch et al., 2022). Moreover, despite policy support at both EU and global levels (EEA, 2020; Frantzeskaki et al., 2019), operationalising NBS in teaching remains unclear. As Nesshöver et al. (2017) note, although NBS serve as a boundary concept, translating them into actionable curricula requires institutional frameworks, teacher training, and clearly defined learning outcomes. Recent evidence supports this view: for example, in Croatia, Czechia, and Slovenia, translating NBS research into curricula has resulted in only a limited number of courses, many of which remain elective rather than compulsory, despite being aligned with emerging research areas such as blue-green infrastructure and ecosystem services (Potočki et al., 2023).The study highlights the importance of stronger integration between HE and TVET to mainstream NBS holistically. Flexible, practice-oriented formats, such as micro-credentials, modular courses, and interdisciplinary collaboration, can help build capacity for diverse learners and align with initiatives like the European GreenComp framework (Bianchi et al., 2022), which promotes sustainability competences across educational levels. Embedding NBS education in local and regional contexts through living labs, real-world projects, and community-based learning further enhances curricular relevance and policy-practice linkages. These place-based and transdisciplinary approaches are increasingly recognised for their transformative potential in supporting societal change (van der Wee et al., 2024; Basnou et al., 2025, Frantzeskaki et al., 2025). Realising this potential requires coordinated actions such as aligning national qualification frameworks with EU strategies, incentivising transdisciplinary collaboration, and investing in educator training that integrates ecological, technical, and social dimensions of sustainability.

Building upon these insights, Fig. 4 provides a concise overview of the key factors shaping the integration of NBS into higher education and TVET. The framework brings together the main policy and institutional drivers, challenges, opportunities, and desired outcomes identified in this study. It highlights how NBS education is embedded within broader European policy agendas and institutional settings, while also being constrained by structural and conceptual barriers such as limited awareness and institutional fragmentation. At the same time, the figure illustrates how emerging opportunities, such as improved teacher training, international collaboration, and whole-institution approaches, can help bridge these gaps. Collectively, these elements point toward the development of stronger NBS competencies, transformative learning experiences, and better preparedness for sustainability transitions.

4.5. Limitations and future research

While this study provides valuable insights into the integration of NBS in higher education and TVET, some limitations should be noted. Although it draws on a mixed-method approach and includes participants from seven EU countries, the study is exploratory and primarily qualitative. The sample largely comprised institutions already engaged in sustainability, which may have introduced a positive bias regarding awareness and commitment to NBS. Additionally, the number of TVET respondents was smaller compared to those from higher education. Furthermore, the study primarily focuses on educators' and institutional perspectives, offering limited insight into how students perceive and engage with NBS. Including the student perspective in future research could provide additional depth and reveal how learners understand, value, and potentially act on NBS-related content. Nevertheless, despite these limitations, the diversity of disciplinary backgrounds, roles, and institutional contexts among participants has enabled us to identify meaningful patterns and opportunities. These findings offer a useful basis for further research and support ongoing efforts to embed NBS in educational practice.

Future research could seek to address these limitations in various ways. First, larger-scale studies, including quantitative surveys, could help assess the extent of NBS integration across a broader and more diverse range of institutions. Second, further research should include a stronger focus on student perspectives, learning outcomes, and long-term impacts, such as the influence of NBS education on career pathways and environmental citizenship. Comparative studies between EU and non-EU countries would also enrich our understanding of how differing policy and governance frameworks shape educational approaches to NBS. Future research could also explore how geographical and climatic contexts shape the understanding and integration of NBS in educational programs. Finally, more systematic analyses of curricula, textbooks, teaching materials, and assessment practices are needed to evaluate not only the presence but also the depth and quality of NBS content across education systems. In addition, future research should establish a clearer set of competencies that can guide the design of dedicated NBS courses. Identifying such competencies, similar to the

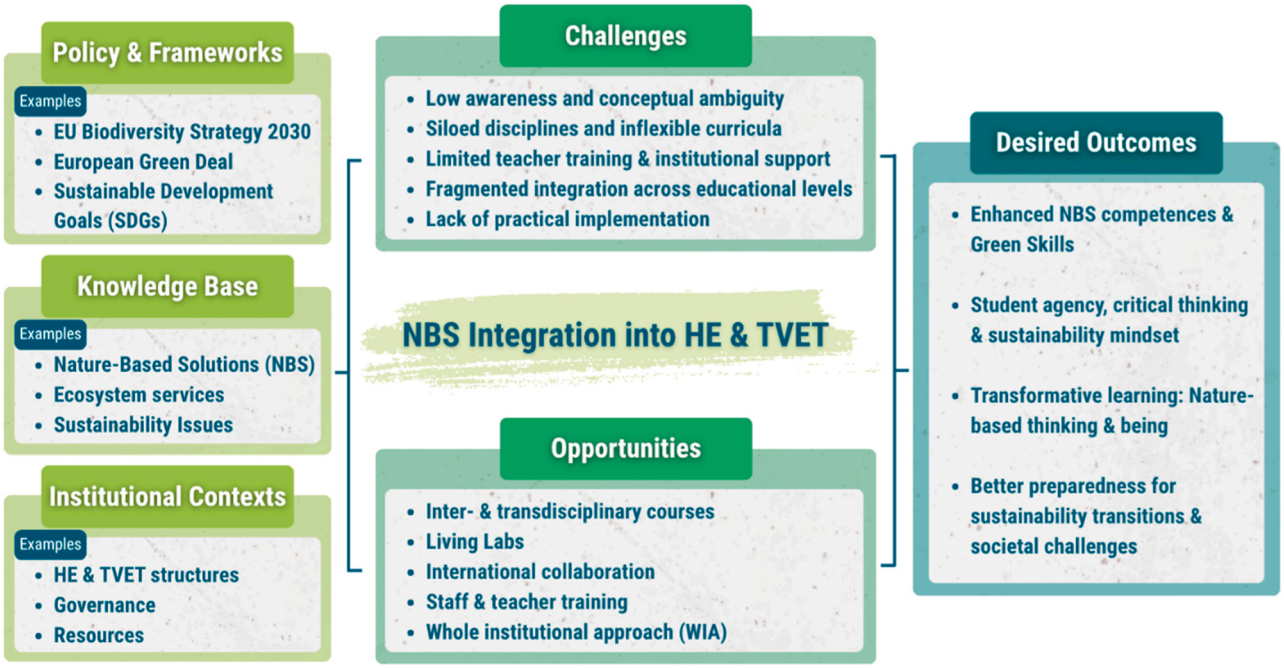

Fig. 4. Key Factors, challenges, and opportunities for integrating NBS into Higher Education and TVET (Own illustration, created with Canva).

work of Vera-Puerto et al. (2020) in defining key skills for water engineers, would provide a structured foundation for curriculum development and ensure that proposed courses align with the knowledge, skills, and attitudes required to address sustainability challenges. By expanding the empirical base and engaging with a wider range of actors, future research can contribute to more inclusive and policy-relevant educational strategies for mainstreaming NBS in support of broader sustainability transitions.

Looking ahead, while NBS offer a valuable framework for addressing ecological and societal challenges, educational systems must move beyond instrumental applications toward deeper paradigmatic shifts. Embedding NBS in curricula should evolve into Nature-Based Thinking, where nature is seen as a co-educator, and ultimately toward Nature-Based Being, a pedagogical orientation that fosters emotional, ethical, and embodied learning. Such a shift supports more transformative approaches aligned with sustainability education, indigenous knowledge systems, and reimagined human-nature relationships essential for lasting transitions.

5. Conclusion

This study contributes to the emerging discourse on sustainability education by providing one of the first cross-country and cross-sectoral analyses of how NBS are understood and integrated into higher education and TVET systems across Europe. Our findings highlight a fragmented yet evolving landscape, characterised by conceptual ambiguity and institutional barriers, but also by growing innovation and educator-led initiatives that are reshaping traditional education models. Embedding NBS into education reflects a broader move toward holistic, transdisciplinary, and practice-oriented learning approaches that are increasingly important for addressing climate change, biodiversity loss, and urban resilience. While persistent challenges remain, such as limited resources, rigid structures, and a lack of clarity, promising developments are emerging, including stakeholder-engaged learning, real-world project work, and increased student interest in sustainability-related careers. Educators are proving to be key drivers of change, supported by EU frameworks such as the Green Deal, Horizon Europe Missions, and the Biodiversity Strategy 2030.

This study provides insights relevant to Europe, but they may also be valuable for other regions, such as Latin America, where the need for NBS is also highly relevant. Cross-regional knowledge exchange, joint educational initiatives, and shared policy learning can foster the mainstreaming of NBS in curricula. To support this process, we recommend that future efforts focus on:

- Developing adaptable definitions and teaching approaches for NBS across different educational levels and contexts;
- Strengthening interdisciplinary and transdisciplinary teaching through institutional support and cross-sectoral collaboration;
- Promoting hands-on, community-based learning that connects education with real-world sustainability challenges;
- Providing targeted training for educators, curriculum developers, and institutional leaders;
- Encouraging international collaboration and the sharing of good practices through global networks and platforms.

Addressing these priorities is essential for embedding NBS into formal education and for strengthening the skills, values, and competencies needed to build inclusive and resilient societies. Education plays a crucial role in shaping the next generation of professionals, citizens, and decision-makers. By enhancing its capacity to support NBS, we take a meaningful step toward a more sustainable and nature-positive future.

CRediT authorship contribution statement

Verena Radinger-Peer: Writing – review & editing, Supervision, Funding acquisition. **Michael Jones:** Writing – review & editing. **Arjen Wals:** Writing – review & editing. **Birthe Uhlhorn:** Writing – review & editing, Visualization, Validation. **Tigran Keryan:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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