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Towards an Integrated Framework for Green Skills Development in Higher Education: A Systematic Literature Review

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Abstract. The transition towards sustainable development and green economies has increased the demand for graduates who combine environmental responsibility, innovation, and professional adaptability. Yet empirical evidence on green skills in higher education remains fragmented across disciplines, terminology, pedagogy, competencies, and institutional practice. This systematic literature review synthesised how green skills are conceptualised, developed, integrated into curricula, and implemented in higher education and proposed an integrated framework. Following PRISMA, searches of Google Scholar, Scopus, ProQuest, Emerald Insight, SAGE Journals, and ScienceDirect identified 319 records; 19 peer-reviewed empirical studies published between 2018 and 2024 met the eligibility criteria and a six-item methodological quality threshold ($\geq 9/12$). Data were extracted using a structured review matrix and analysed through hybrid deductive/inductive thematic synthesis. Five terminology clusters were identified, spanning broad sustainability competencies to discipline-specific technical and professional capabilities. Thirteen studies reported identifiable pedagogical approaches, most frequently experiential and practice-based learning, while nine reported institutional mechanisms including curriculum integration, student-led initiatives, stakeholder partnerships, and workforce alignment. The resulting framework conceptualises green skills development as a context-sensitive, recursive interaction among conceptual orientation, pedagogy, competencies and curriculum, and institutional implementation. It provides an analytical basis for aligning these dimensions and for future empirical validation.

Keywords: curriculum integration; green skills; higher education; institutional implementation; sustainability competencies

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1. Introduction

The transition towards low-carbon economies is reshaping occupational skill requirements and increasing the demand for sustainability-orientated capabilities. Evidence indicates that much of this change will occur within existing jobs and not solely through the creation of entirely new occupations (Organisation for Economic Co-operation and Development, 2024). Substantial employment gains are also projected from climate adaptation and mitigation, with environmental management identified among the fastest-growing skill areas (World Economic Forum, 2025). Green and digital transitions likewise require retraining, upskilling, and labour-market support across skill levels (International Labour Organization, 2024).

Yet educational preparedness remains uneven: 47% of the 100 national curriculum frameworks that were examined did not mention climate disruption, and only 23% of surveyed teachers felt prepared to address climate action (United Nations Educational Scientific and Cultural Organization, 2024). These developments increase the importance of competencies that combine environmental awareness, technical expertise, and adaptability (Cabral & Dhar, 2021; Fuchs, 2024), making green skills a strategic priority for education and workforce development (Kwauk & Casey, 2022; Pavlova, 2019).

Green skills encompass the knowledge, competencies, values, and behaviours needed to contribute to sustainable development and environmentally responsible practice. Beyond technical expertise, they include systems thinking, problem-solving, communication, collaboration, innovation, and ethical responsibility (Pavlova, 2019). In practice, these capabilities support both employability and participation in wider sustainability transitions. Higher education is central to green skills development because universities prepare future professionals and decision-makers through curriculum, teaching, research, campus initiatives, and external partnerships. These functions position higher education to connect sustainability principles with disciplinary learning and professional practice (Lozano et al., 2022).

Research spans sustainability education, science and engineering, entrepreneurship, architecture, renewable energy, logistics, and vocational education. Competency-orientated studies emphasise transferable capabilities such as systems thinking, collaboration, leadership, and ethical responsibility (Cabral & Dhar, 2021; Fodor et al., 2021; Lozano et al., 2022). Discipline-orientated studies focus on specialised technical competencies (Alvarez-Risco et al., 2021; Kumar et al., 2024; Lin et al., 2018), while institution- and community-orientated studies foreground mentoring, student initiatives, stakeholder partnerships, and campus practice (Aloisio et al., 2022; Hamann et al., 2021; Okada & Gray, 2023). These strands show that green skills development combines transferable competence, disciplinary expertise, and opportunities for application.

The central research problem is the fragmented and context-dependent way that green skills are conceptualised, developed, and implemented in higher education. Some studies frame them primarily as employability and workforce competencies. Others emphasise environmental responsibility, climate action, and social transformation (Kwauk & Casey, 2022; Pavlova, 2019). Curricular models range from stand-alone modules to interdisciplinary and institution-wide integration, and the evidence spans diverse methods and disciplinary settings. This heterogeneity limits direct comparison and leaves unresolved how conceptual, pedagogical, curricular, and institutional dimensions interact.

Previous reviews have addressed green competencies, discipline-specific sustainability curricula, institutional sustainability, and more recently, the connection between sustainability competences and pedagogical approaches, but none integrates all four dimensions examined here (Cabral & Dhar, 2021; Figueiró & Raufflet, 2015; Menon & Suresh, 2020; Ortiz-Martínez et al., 2026; Thürer et al., 2018). This review addresses this gap by synthesising terminology, pedagogy, competencies and curriculum, and institutional implementation within one analytical framework.

This study aimed to provide a critical synthesis of the empirical evidence on how green skills are conceptualised, developed through pedagogy and curriculum, and implemented across higher education contexts. A second objective was to develop an integrated framework that identifies evidence gaps and directions for future research. Four research questions guided the review:

- RQ1:** What terminologies are used to conceptualise green skills in higher education?
- RQ2:** What pedagogical approaches are employed to develop green skills in higher education?
- RQ3:** How are green skills competencies represented within higher education curricula?
- RQ4:** How do contextual factors shape the institutional and campus-level implementation of green skills in higher education?

The review makes three related contributions. Theoretically, it conceptualises green skills as a multidimensional construct linking conceptual orientation, pedagogy, competency development, curriculum integration, and institutional implementation. Methodologically, thematic synthesis across diverse disciplinary and geographical contexts identifies patterns among dimensions often examined separately. Practically, the framework provides an analytical lens for considering alignment among graduate competencies, teaching, curriculum, institutional practice, and stakeholder engagement, supporting higher education leaders, curriculum developers, educators, and researchers.

2. Literature Review

2.1 Green Skills and Sustainability Competencies

Green skills are conceptualised differently across policy and scholarly traditions. One perspective frame them through Education for Sustainable Development, emphasising knowledge, skills, values, attitudes, and responsible action (United Nations Educational Scientific and Cultural Organization, 2017). A task- and labour-market perspective instead treats skills as 'green' through their application to sustainability-orientated occupations and production processes (Organisation for Economic Co-operation and Development, 2024). A related labour-market perspective combines specific environmental skills with broader technical, cognitive, socio-emotional, and transferable capabilities required for green jobs and a just transition (International Labour Organization, 2019). Justice-orientated perspectives extend this view by linking climate action with equity, gender empowerment, and climate justice (Kwauk & Casey, 2022).

GreenComp adopts a broad competence-based perspective, organising 12 competencies around sustainability values, complexity, future-orientated thinking, and action (Bianchi et al., 2022). By contrast, greater emphasis is placed on environmental industries, changing labour-market requirements, and the responsiveness of technical and vocational education (Pavlova, 2019) while still recognising transferable capabilities and partnerships among education, government, industry, and civil society.

The concept has broadened over time. Earlier policy discussions emphasised technical and occupational capabilities for low-carbon industries and resource-efficient work (Organisation for Economic Co-operation and Development & European Centre for the Development of Vocational Training, 2014). More recent frameworks include sustainability literacy, systems thinking, reflection, innovation, collaboration, leadership, ethics, and individual or collective action (Bianchi et al., 2022; United Nations Educational Scientific and Cultural Organization, 2017). Green skills now encompass both occupational preparation and participation in wider environmental, economic, and social transitions.

These perspectives are complementary but imply different educational priorities. Labour-market approaches emphasise occupational standards, reskilling, and industry alignment, whereas the United Nations Educational, Scientific and Cultural Organization (UNESCO) and GreenComp foreground cross-curricular learning, values, systems thinking, and action. For the purposes of this review, the term green skills serve as an umbrella concept, consistent with the distinction between generic and specific green competencies (Cabral & Dhar, 2021). The concept covers technical and transferable abilities, knowledge, values, attitudes, and action competencies that support environmentally sound, socially just, and economically viable transitions.

2.2 Green Skills Development in Higher Education

Higher education must prepare graduates for both sustainability-orientated labour markets and broader societal transitions. Meeting this challenge requires more than environmental knowledge; students must analyse complex systems, collaborate across disciplines, evaluate competing values, apply disciplinary knowledge, and demonstrate competence in authentic contexts.

Experiential, project-based, problem-based, and laboratory learning can be understood through Experiential Learning Theory and constructivism. Experiential learning cycles through experience, reflection, conceptualisation, and experimentation (Kolb, 1984), while constructivism emphasises active knowledge construction. Constructive alignment connects intended outcomes, teaching activities, and assessment so that students can practise and demonstrate sustainability competencies (Biggs, 1996). These perspectives help to explain the relevance of active and inquiry-orientated learning for systems thinking, problem-solving, innovation, and technical green competencies (Lozano et al., 2022; Martín-Garin et al., 2021).

Situated Learning Theory explains the value of mentoring, collaborative projects, campus initiatives, community engagement, and industry partnerships because competence develops through participation in authentic social and professional practices (Lave & Wenger, 1991). Transformative Learning Theory adds the role of critical reflection in reconsidering assumptions, values, professional responsibilities, and social inequalities (Mezirow, 1991). Together, these perspectives connect green skills development with both situated practice and changes in values, agency, and responsibility.

Competency-Based Education translates these learning processes into explicit outcomes and demonstrable performance (Gervais, 2016). In green skills education, competency-based design can align transferable sustainability competencies with discipline-specific capabilities and assess them through projects, portfolios, simulations, demonstrations, reflection, and authentic problem-solving. Experiential and constructivist theories explain active knowledge development; situated learning explains authentic participation; transformative learning explains changes in perspective; and competency-based education links these processes to assessable outcomes.

2.3 Curricular and Institutional Integration of Green Skills

Green skills become educationally meaningful when sustainability competencies are translated into coherent curricula, learning outcomes, and institutional practices. Higher education must determine how broad and discipline-specific competencies are embedded in programmes, connected with professional requirements, and applied in academic, occupational, and societal contexts (Fuchs, 2024; Lozano et al., 2022).

Curriculum integration may occur through dedicated modules, embedded disciplinary content, interdisciplinary programmes, or programme-level outcomes and graduate attributes. Cross-curricular approaches are well suited to transferable competencies, whereas specialised modules can develop

sector-specific technical capabilities. Effective design, therefore, depends on alignment between generic sustainability competence and disciplinary expertise (Cabral & Dhar, 2021; Lozano et al., 2022).

Institutional conditions matter because sustainability learning extends beyond formal curricula. Policies, campus practices, student initiatives, interdisciplinary collaboration, and partnerships with industries and communities can reinforce classroom learning. Green skills development is strengthened when sustainability forms part of the institutional learning environment instead of being left to isolated courses or individual educators (Krüger et al., 2025; Menon & Suresh, 2020; Ssekamatte, 2023).

Previous reviews remain comparatively compartmentalised. Green competencies have been synthesised mainly from organisational and human-resource perspectives, with limited attention to how higher education develops them through pedagogy and curriculum (Cabral & Dhar, 2021). Reviews of management and engineering education provide valuable disciplinary insights but do not systematically connect competency conceptualisation with institutional implementation (Figueiró & Raufflet, 2015; Thürer et al., 2018). Broader institutional reviews link education, research, operations, and community engagement but prioritise institutional sustainability and give less attention to the developmental relationships among green skills, pedagogy, curriculum, and competence formation (Menon & Suresh, 2020). The present review integrates these strands through four interconnected analytical domains within a context-sensitive framework.

3. Methodology

This systematic literature review synthesised empirical evidence on green skills development in higher education following PRISMA guidance for transparent and rigorous reporting (Page et al., 2021). Searches were conducted from 14 December to 28 December 2024 across Google Scholar, Scopus, ProQuest, Emerald Insight, SAGE Journals, and ScienceDirect. Eligible records were English-language, peer-reviewed empirical journal articles published between 2018 and 2024 that examined green skills, sustainability competencies, or related capabilities in higher education.

The core search string was ("green skills" OR "green competencies" OR "sustainability competencies" OR "sustainability education" OR "green curriculum") AND ("higher education" OR university OR universities OR college). Syntax was adapted to each platform; Google Scholar used equivalent phrase-based combinations. Year and language filters were applied where supported, with remaining criteria assessed during screening.

Predefined eligibility criteria were structured using Population, Intervention/Interest, Comparison, and Outcome (PICO), supplemented by article type, publication type, language, and year. The population covered higher education students, educators, programmes, and institutions, and the intervention/interest covered green or sustainability-orientated competencies,

pedagogy, curriculum, and institutional practice. A comparator was not mandatory because the review synthesised heterogeneous empirical studies and did not evaluate a single intervention. Eligible outcomes concerned competencies, pedagogical processes, curriculum, workforce capabilities, or institutional implementation. Table 1 summarises the criteria.

Table 1: Inclusion/exclusion criteria

Criterion	Inclusion	Exclusion
Population (P) / Educational context	Higher education institutions, including students, educators, academic programmes, or institutional settings	Primary, secondary, early childhood, or non-formal education contexts.
Intervention/Interest (I)/Topic	Green skills, green competencies, sustainability competencies, sustainability-orientated education, pedagogical approaches, curriculum development, or institutional sustainability practices	Studies unrelated to green skills, sustainability competencies, or sustainability-orientated education.
Comparison (C)	No mandatory comparator was required; comparative studies involving pedagogical approaches, programmes, groups, institutions, or educational settings were eligible where applicable	Studies were not excluded solely because they lacked a comparison group or condition.
Outcome (O)	Empirical findings related to green or sustainability competencies, pedagogical processes, curriculum development, workforce-related capabilities, or institutional implementation	Studies that did not report empirical findings relevant to green skills or sustainability-orientated competency development.
Article type	Empirical research articles employing quantitative, qualitative, or mixed-methods designs	Editorials, review articles, conceptual papers without empirical evidence, abstracts, corrections, letters, retracted articles, and other non-empirical article types.
Publication type	Peer-reviewed journal articles	Preprints, conference papers,

Criterion	Inclusion	Exclusion
		book chapters, books, reports, theses, images, and other non-journal publications.
Language	English	Languages other than English.
Publication year	2018–2024	Published before 2018 or after 2024.

Methodological quality was assessed against six criteria: clarity of objectives, methodological transparency, adequacy of data collection, appropriateness of analysis, relevance to the review, and clarity of findings. Each criterion was scored 0–2, giving a maximum of 12; studies required at least 9/12 (75%) for inclusion. Two reviewers appraised all 19 eligible studies independently. Of 114 criterion-level ratings, 104 were identical (91.2% agreement): 100% for objectives, methodological transparency, relevance, and findings; 68.4% for data collection; and 78.9% for data analysis. All disagreements were one-point differences that were resolved by consensus, and all 19 studies met the threshold.

The search identified 319 records. After duplicate removal, four reviewers independently screened titles and abstracts, then assessed potentially eligible full texts using the predefined PICO-guided criteria. Eligibility differences were resolved by consensus. Exclusions concerned topic relevance, non-higher-education contexts, ineligible publication or article types, language, or publication year. Nineteen studies met all eligibility and quality criteria and entered the final synthesis. Figure 1 reports the complete selection process and exclusion reasons.

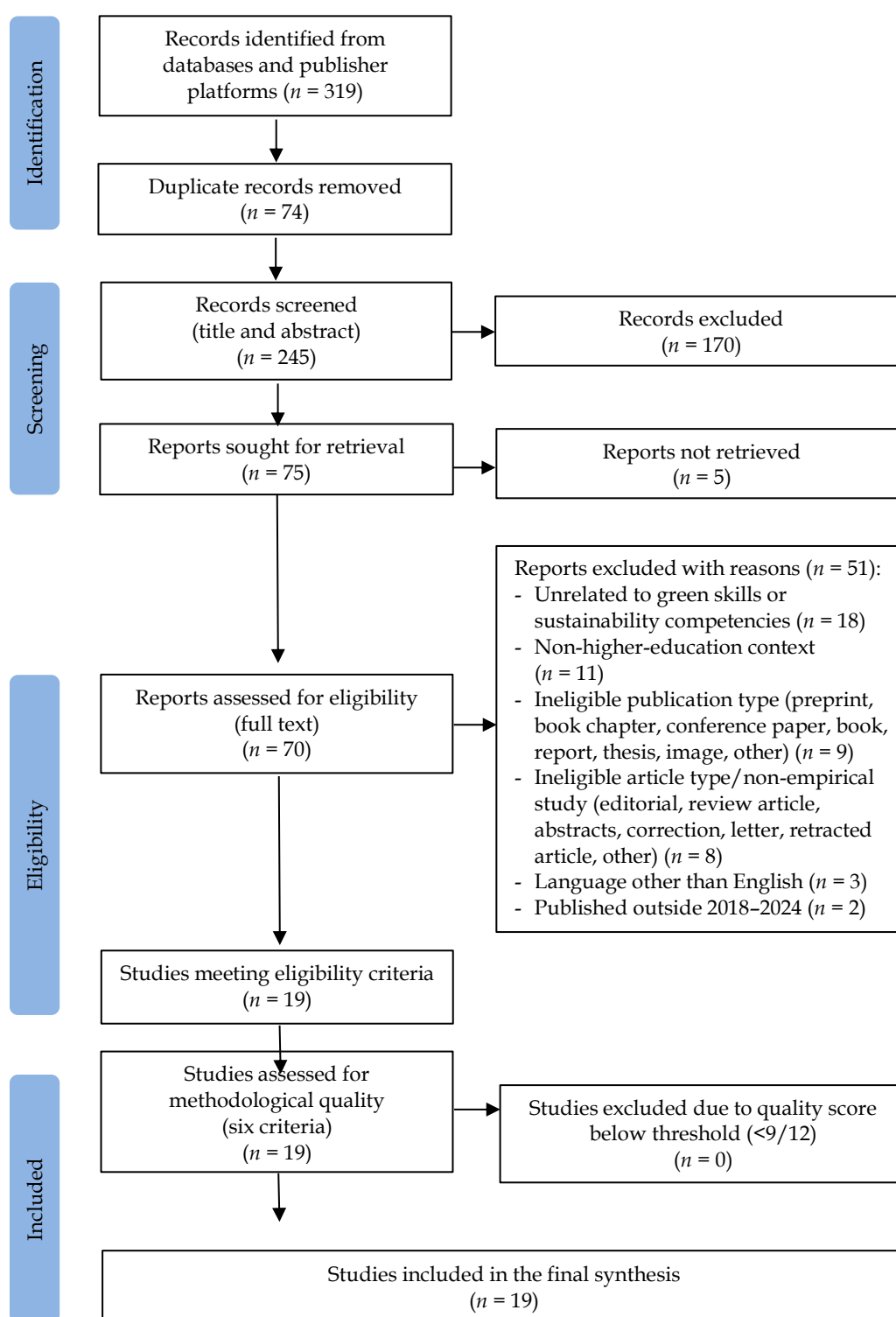


Figure 1: PRISMA flowchart of the study selection process

Data from the 19 studies were extracted into a structured Microsoft Excel matrix and covered publication details, geographical and disciplinary context, research design, participants or setting, terminology, pedagogy, competency domains, curriculum approaches, institutional implementation, and key findings. Excel was

also used to manage coding decisions and to compare study characteristics; no specialised qualitative-analysis software was used. Descriptive analysis summarised publication, geographical, disciplinary, and methodological patterns.

The qualitative synthesis used a hybrid deductive/inductive thematic approach. The four research questions defined the initial domains: terminology, pedagogy, competencies and curriculum, and institutional/campus implementation. Within each domain, findings were coded inductively for recurring concepts, differences, and contextual variation; similar codes were consolidated into higher-order categories and thematic clusters. Thus, the analytical domains were deductive, while subcategories and themes emerged from the empirical evidence.

Two reviewers independently coded the studies in Excel using the same framework and compared code, category, and theme assignments. Differences were resolved by consensus, with definitions refined where necessary. The final structure was checked against the extracted evidence for traceability and alignment with the research questions. Cross-domain relationships informing the integrated framework were likewise checked against recurring evidence and were reported as synthesis-derived conceptual linkages; they were not treated as tested causal relationships.

4. Results

4.1 Study Characteristics and Research Trends

Nineteen empirical studies published between 2018 and 2024 met the eligibility and quality criteria. Table 2 shows broad geographical coverage across Asia, Europe, Africa, North America, Latin America, and cross-context settings, with disciplines ranging from sustainability and environmental education to chemistry, architecture, entrepreneurship, renewable energy, logistics, climate education, and digital sustainability. This breadth positions green skills as a cross-disciplinary higher education concern, not merely a niche environmental field.

Table 2: Characteristics of the reviewed studies

No.	Authors, Year	Country/ Region	Discipline/ Field	Method	Research Focus
1	Lin et al., 2018	China	Chemistry Education	Quantitative	Green chemistry laboratory experiment
2	Dai & Hwang, 2019	Taiwan	Design Education	Qualitative	Bamboo craft and sustainability education
3	Gupta et al., 2019	India	Building Education	Quantitative	Green building performance education
4	Celadyn, 2020	Poland	Interior Architectural Design Education	Quantitative	Sustainable interior design education

No.	Authors, Year	Country/ Region	Discipline/ Field	Method	Research Focus
5	Alvarez-Risco et al., 2021	Ecuador	Entrepreneurship Education	Mixed Methods	Green entrepreneurship education
6	Fodor et al., 2021	Hungary	Sustainability Education	Qualitative	Sustainability competence development
7	Gherheș et al., 2021	Romania	Environmental Education	Quantitative	Environmental routines and campus sustainability
8	Hamann et al., 2021	Germany	Sustainability Education	Mixed Methods	Student-led sustainability initiatives
9	Aloisio et al., 2022	United States	Urban Ecology Education	Mixed Methods	Urban ecology mentoring
10	Yeerum et al., 2022	Thailand	Chemistry Education	Quantitative	Green analytical chemistry laboratory learning
11	Zacchia et al., 2022	Tanzania and Uganda	Sustainability Education	Mixed Methods	Sustainable energy and green economy education
12	Predan & Černe Oven, 2023	Slovenia	Sustainability and Design Education	Qualitative	Sustainability-orientated pedagogy
13	Ssekamatte, 2023	Uganda and Tanzania	Climate Change Education	Qualitative	Climate change education in higher education
14	Deriu & Gallo, 2024	Italy	Higher Education Studies	Quantitative	Green degree programmes
15	Jin et al., 2024	China	Logistics Education	Qualitative	Green logistics talent development
16	Kumar et al., 2024	Hungary/ International	Renewable Energy Education	Mixed Methods	Green energy transition education
17	Lo, 2024	Hong Kong	Digital Sustainability Education	Qualitative	Digital green skills and sustainability
18	Maniatis, 2024	United States	Sustainability Education	Quantitative	Sustainability education outcomes
19	Chen et al., 2024	China	Building Education	Quantitative	Green building learning

Research activity increased markedly after 2020: four studies were published in 2018–2020 compared with 15 (78.9%) in 2021–2024, with six (31.6%) of these being published in 2024. This concentration coincides with stronger international attention to the Sustainable Development Goals, low-carbon transitions, green workforce development, and post-pandemic sustainability agendas (International Labour Organization, 2024; Organisation for Economic Co-operation and Development, 2024), indicating growing higher education interest in sustainability-orientated occupational competencies.

Methodological approaches were also diverse: eight studies were quantitative; six were qualitative; and five were mixed methods. The quantitative designs typically examined learning outcomes, perceptions, behaviour, or competency development; the qualitative studies explored curriculum, implementation, experience, and context; and the mixed-methods research combined outcome and process evidence. This heterogeneity reflects the field's multidimensional scope but limits direct comparison across disciplines and institutions.

4.2 Green Skills Terminologies

Terminology varied substantially across the 19 studies. Inductive coding identified five higher-order clusters, as shown in Table 3: (1) sustainability competencies and education, (2) climate and environmental action, (3) discipline-specific green education, (4) green economy and workforce transition, and (5) digital sustainability skills. These clusters emerged from recurring patterns and were not imposed by a predetermined framework.

Table 3: Identified green skills terminologies

Conceptual Cluster	Terminologies/Orientation	Representative Studies
Sustainability Competencies and Education	Sustainability competencies; ESD; sustainability education; sustainability transition; sustainability-orientated pedagogy	Dai & Hwang, 2019 ; Fodor et al., 2021 ; Hamann et al., 2021 ; Maniatis, 2024 ; Predan & Černe Oven, 2023
Climate and Environmental Action	Environmental behaviour; urban ecology learning; climate change education	Aloisio et al., 2022 ; Gherheș et al., 2021 ; Ssekamatte, 2023
Discipline-Specific Green Education	Green chemistry; sustainable architectural design; green building; green entrepreneurship; green logistics	Alvarez-Risco et al., 2021 ; Celadyn, 2020 ; Chen et al., 2024 ; Gupta et al., 2019 ; Jin et al., 2024 ; Lin et al., 2018 ; Yeerum et al., 2022
Green Economy and Workforce Transition	Sustainable energy; green degree programmes; green energy transition	Deriu & Gallo, 2024 ; Kumar et al., 2024 ; Zacchia et al., 2022
Digital Sustainability Skills	Digital sustainability; integration of digital literacy and eco-conscious practices	Lo, 2024

ESD: Education for Sustainable Development

The sustainability competencies and education cluster had the broadest orientation, emphasising transferable capacities such as sustainability understanding, collaboration, reflection, and action (Dai & Hwang, 2019; Fodor et al., 2021; Hamann et al., 2021; Maniatis, 2024; Predan & Černe Oven, 2023). Climate and environmental action focused more on environmental behaviour, climate responses, and ecological or community engagement (Aloisio et al., 2022; Gherheş et al., 2021; Ssekamatte, 2023). Both primarily framed green skills as broad capabilities for sustainability participation.

Discipline-specific terminology translated sustainability into professional practice. Examples included green chemistry, building, design, entrepreneurship, and logistics (Alvarez-Risco et al., 2021; Celadyn, 2020; Chen et al., 2024; Gupta et al., 2019; Jin et al., 2024; Lin et al., 2018; Yeerum et al., 2022). The green economy and workforce cluster emphasised energy transitions, green degree pathways, and employability (Deriu & Gallo, 2024; Kumar et al., 2024; Zacchia et al., 2022), while digital sustainability linked digital literacy with environmentally responsible technology use (Lo, 2024).

The terminology formed a continuum from transferable sustainability competence to specialised technical and occupational capability, with climate action and digital competencies between these poles. This variation corresponded with different educational strategies; broad terminology tended to support interdisciplinary or cross-curricular integration, whereas discipline- and sector-specific terminology aligned more closely with specialised modules, professional preparation, and technical competency development.

4.3 Pedagogical Approaches for Green Skills Development

Regarding the pedagogical approach, 13 of the 19 studies reported identifiable pedagogical approaches; six focused on competencies, programmes, workforce alignment, transitions, or institutional practice without specifying teaching methods. Seven categories were identified, as shown in Table 4. Experiential and practice-based learning was most frequent ($n = 4$), followed by workshops, training, and coaching ($n = 3$). Laboratory/experimental, digital/simulation, and structured instructional approaches each appeared in two studies, while case/problem-based and research/inquiry approaches each appeared once. Categories were non-exclusive because some studies used multiple strategies.

Table 4: Pedagogical approaches for green skills development

Pedagogical Approach	Learning Orientation	Frequency (n)	Representative Studies
Experiential and Practice-Based Learning	Applied, real-world, and practice-orientated learning	4	Aloisio et al., 2022; Celadyn, 2020; Dai & Hwang, 2019 ; Hamann et al., 2021
Workshop, Training, and Coaching Approaches	Guided learning, mentoring, coaching, feedback, and competency development	3	Alvarez-Risco et al., 2021 ; Hamann et al., 2021 ; Predan & Černe Oven, 2023
Laboratory-Based and Experimental Learning	Laboratory activities, experimentation, and practical scientific investigation	2	Lin et al., 2018 ; Yeerum et al., 2022
Digital and Simulation-Based Learning	Digital technologies, simulations, and technology-supported learning	2	Jin et al., 2024; Lo, 2024
Direct Instruction and Structured Educational Intervention	Formal instruction and structured interventions supporting learning outcomes	2	Chen et al., 2024; Maniatis, 2024
Case-Based and Problem-Based Learning	Analysis of sustainability-related cases and problems	1	Gupta et al., 2019
Research-Based and Inquiry-Orientated Learning	Investigation, inquiry, and research-orientated learning	1	Aloisio et al., 2022

Experiential and practice-based learning was the most recurrent pattern. Across different contexts, Celadyn (2020), Dai and Hwang (2019), Hamann et al. (2021), and Aloisio et al. (2022) engaged learners with sustainability-related problems, practices, or initiatives. Its recurrence suggests a strong role in linking sustainability concepts with professional practice, reflection, collaboration, and problem-solving, but heterogeneous designs and outcomes preclude claims of superior effectiveness.

Laboratory and experimental learning appeared in the chemistry-orientated studies by Lin et al. (2018) and Yeerum et al. (2022), while Maniatis (2024) and Chen et al. (2024) used structured interventions with quantitative outcome measures. These studies offer relatively direct evidence of learning within defined instructional settings, but their disciplinary concentration prevents generalisation to other pedagogies or contexts.

Workshops, training, and coaching in the studies of Alvarez-Risco et al. (2021), Hamann et al. (2021), and Predan and Černe Oven (2023) emphasised mentoring, feedback, collaboration, and guided competency development. Compared with laboratory approaches, they addressed broader behavioural, interpersonal,

entrepreneurial, and sustainability-orientated capabilities, illustrating that pedagogical relevance depends on the competency that is targeted.

Less frequent approaches included digital and simulation-based learning (Jin et al., 2024; Lo, 2024), case- and problem-based learning (Gupta et al., 2019), and research- and inquiry-orientated learning (Aloisio et al., 2022). These approaches extended green skills development through analysis, investigation, decision-making, and technology-supported problem-solving, but their limited representation prevented strong comparative claims.

No single pedagogy could be identified as universally superior. Experiential learning was the most represented, while laboratory and structured interventions provided more specific outcome evidence. Furthermore, coaching, digital, problem-based, and inquiry approaches contributed complementary dimensions. Green skills development appeared to require context-sensitive combinations of pedagogies aligned with competencies and disciplinary requirements. The six studies without an identifiable pedagogy pointed to a gap between defining desired competencies and specifying how they are taught.

4.4 Green Skills Competencies and Curriculum Development

Six interrelated competency domains were identified across the 19 studies. These comprised generic sustainability competencies; discipline-specific technical and professional competencies; green employability, innovation, and entrepreneurship; leadership, collaboration, and social action; digital and systems-thinking competencies; and climate change and environmental behaviour. Table 5 shows how these domains are embedded through cross-curricular integration, specialised modules, professional pathways, mentoring, and technology-supported learning.

Table 5: Green skills competencies and curriculum development approaches

Competency Domain	Curriculum Development Approach	Representative Studies
Generic Sustainability Competencies	Sustainability-orientated courses, programme learning outcomes, interdisciplinary learning, and ESD-orientated curricula	Dai & Hwang, 2019; Fodor et al., 2021; Hamann et al., 2021; Maniatis, 2024; Predan & Černe Oven, 2023
Discipline-Specific Technical and Professional Green Competencies	Laboratory courses, design studios, green building education, logistics curricula, chemistry education, and renewable energy programmes	Celadyn, 2020; Chen et al., 2024; Gupta et al., 2019; Jin et al., 2024; Kumar et al., 2024; Lin et al., 2018; Yeerum et al., 2022
Green Employability, Innovation, and Entrepreneurship Competencies	Green entrepreneurship education, industry-orientated curricula, sustainable energy pathways, green degree programmes, and professional preparation	Alvarez-Risco et al., 2021; Deriu & Gallo, 2024; Jin et al., 2024; Kumar et al., 2024; Zacchia et al., 2022

Competency Domain	Curriculum Development Approach	Representative Studies
Leadership, Collaboration, and Social Action Competencies	Student-led initiatives, mentoring, collaborative projects, coaching, and applied sustainability engagement	Aloisio et al., 2022; Hamann et al., 2021; Predan & Černe Oven, 2023
Digital and Systems-Thinking Competencies	Digital sustainability learning, systems-orientated activities, data-supported learning, and technology-enabled sustainability education	Fodor et al., 2021; Jin et al., 2024; Lo, 2024
Climate Change and Environmental Behaviour Competencies	Climate change education, environmental behaviour learning, urban ecology, and campus sustainability practices	Aloisio et al., 2022; Gherheş et al., 2021; Ssekamatte, 2023

ESD: Education for Sustainable Development

Generic sustainability competencies included sustainability literacy, critical and systems thinking, collaboration, reflection, ethical responsibility, and engagement with complex challenges (Dai & Hwang, 2019; Fodor et al., 2021; Hamann et al., 2021; Maniatis, 2024; Predan & Černe Oven, 2023). These align closely with UNESCO competencies (United Nations Educational Scientific and Cultural Organization, 2017) and GreenComp areas concerned with complexity and sustainability action (Bianchi et al., 2022), indicating strong correspondence with established transferable sustainability capabilities.

The empirical studies extended these frameworks through discipline-specific technical and professional capabilities. Examples include chemistry, architecture, green building, renewable energy, and logistics (Celadyn, 2020; Chen et al., 2024; Gupta et al., 2019; Jin et al., 2024; Kumar et al., 2024; Lin et al., 2018; Yeerum et al., 2022). Rather than merely replicating the generic competencies articulated in established frameworks, the discipline-specific competencies identified in this review complement these frameworks by translating broad sustainability principles into profession-specific knowledge, methods, technologies, and practices.

Green employability, innovation, and entrepreneurship provided another extension. Studies of entrepreneurship, energy, green degrees, logistics, and workforce preparation connected sustainability competencies directly with occupational change and sectoral transformation (Alvarez-Risco et al., 2021; Deriu & Gallo, 2024; Jin et al., 2024; Kumar et al., 2024; Zacchia et al., 2022). Green skills development thus combines sustainability citizenship with preparation for changing professional roles.

Leadership, collaboration, social action, environmental behaviour, and digital capability further connected the empirical domains with international models. Student-led and mentoring studies corresponded with collaborative and collective-action competencies; climate and behaviour studies aligned with valuing and acting for sustainability. Digital sustainability and systems-orientated capabilities constituted an emerging area that combines sustainability thinking with digital technologies and professional practice, extending rather than duplicating existing competency models.

Several internationally recognised sustainability competencies – anticipatory and normative thinking, futures literacy, adaptability, fairness, self-awareness, and political agency – were less consistently articulated in the empirical corpus (Bianchi et al., 2022; United Nations Educational Scientific and Cultural Organization, 2017). The corpus more frequently operationalised competencies directly linked to curriculum, professional application, behaviour, and employability. Future curriculum research could examine how these less visible normative, future-orientated, and civic dimensions can be integrated with technical competencies.

The six domains aligned with international sustainability frameworks while extending them towards disciplinary expertise, employability, entrepreneurship, digital sustainability, climate action, and professional practice. The evidence supports curricula in which transferable sustainability capabilities provide a common foundation for discipline-specific, technological, and workforce-orientated application.

4.5 Campus-Level Implementation of Green Skills

Nine of the 19 studies reported sufficiently explicit institutional or campus-level implementation. Table 6 groups these mechanisms into sustainability governance and academic pathways, curriculum and programme integration, campus behaviour and routines, student-led initiatives, community and stakeholder partnerships, industry and workforce alignment, and institutionally supported climate and sustainability action. The categories overlap because institutions may use several mechanisms simultaneously.

Table 6: Campus-level implementation of green skills

Institutional Implementation Area	Implementation Focus	Representative Studies
Institutional Sustainability Governance and Academic Pathways	Embedding sustainability into institutional strategies, academic pathways, learning structures, and institutional support systems	Deriu & Gallo, 2024; Fodor et al., 2021; Ssekamatte, 2023
Curriculum-System and Programme-Level Implementation	Integrating green skills through programme design, interdisciplinary pathways, curriculum structures, and specialised programmes	Jin et al., 2024; Kumar et al., 2024; Zacchia et al., 2022
Campus Sustainability Behaviour and Routines	Reinforcing sustainability through environmental behaviour, responsible resource use, and sustainability-related routines	Gherheş et al., 2021
Student-Led and Experiential Sustainability Initiatives	Developing green skills through student-led projects, mentoring, applied research, and sustainability engagement	Aloisio et al., 2022; Hamann et al., 2021
Community and Stakeholder Partnerships	Connecting university learning with external stakeholders and societal sustainability priorities	Aloisio et al., 2022; Ssekamatte, 2023; Zacchia et al., 2022
Industry and Workforce Alignment	Linking curricula and green competencies with sectoral needs, employability, renewable energy, and green professional pathways	Jin et al., 2024; Kumar et al., 2024
Institutional Climate and Sustainability Action	Supporting climate and sustainability learning through institutional support, student action, and sustainability-orientated initiatives	Gherheş et al., 2021; Hamann et al., 2021; Ssekamatte, 2023

Institutional implementation varied by context. European studies more frequently emphasised academic structures, competence-orientated curricula, green pathways, and student-led initiatives, as illustrated by evidence from Hungary, Germany, and Italy. These studies indicated greater institutionalisation of sustainability within academic structures and learning environments beyond individual courses.

North American evidence was more strongly represented by experiential and student-engagement mechanisms. Aloisio et al. (2022), for example, linked mentoring and applied urban ecology research with participation and peer learning. Because few North American studies met the eligibility criteria, this pattern should be read cautiously and not considered representative of the region as a whole.

African studies emphasised institutional support, interdisciplinary programmes, and links between sustainability education and wider development or energy-transition priorities. Evidence from Uganda and Tanzania highlighted both university support for climate education and interdisciplinary learning for sustainable energy and the green economy, suggesting that institutional capacity and societal priorities shape implementation.

Several Asian studies embedded green skills more directly within disciplinary, technological, and profession-orientated programmes, including logistics, chemistry, digital sustainability, building education, and laboratory learning. Compared with whole-institution or student-led approaches, these studies operationalised green skills more directly through specialised academic and professional pathways.

Industry and stakeholder alignment added another distinction. Jin et al. (2024) and Kumar et al. (2024) connected green skills with logistics, renewable energy, employability, and workforce transition. By contrast, Hamann et al. (2021), Aloisio et al. (2022), and Ssekamatte (2023) emphasised participation, institutional support, climate action, and social engagement. Implementation varied with programme purpose and geography.

A systematic comparison between comprehensive and technical institutions was not possible because institutional types were inconsistently reported. Nevertheless, technical and profession-orientated studies tended to emphasise specialised curricula, laboratories, sectoral competencies, and workforce alignment, whereas broader sustainability studies more often stressed institutional support, student initiatives, interdisciplinary learning, and academic pathways. This was an evidence pattern, not a definitive institutional typology.

No single institutional model captured the variation across contexts. European evidence more visibly emphasised academic institutionalisation and student-led structures; African studies foregrounded institutional support and links with climate and development priorities; and several Asian studies showed stronger discipline- and profession-orientated integration. Across contexts, governance, curriculum, participation, partnerships, and workforce alignment operated as complementary mechanisms shaped by disciplinary profiles, institutional capacity, and sustainability priorities.

5. Discussion

The evidence positions green skills along a continuum from broad sustainability capabilities to discipline-specific professional competencies, reflecting the dual role of higher education in preparing graduates for sustainability-orientated citizenship and changing labour markets. This continuum explains terminology ranging from sustainability competence and climate education to green chemistry, logistics, renewable energy, and digital sustainability. The variation is better explained by differences in educational purpose and professional application. It is consistent with multidimensional accounts of green competencies (Cabral & Dhar, 2021) and with the distinctions between broad

sustainability education and occupationally orientated green skills discussed by Pavlova (2019) and Fuchs (2024).

Disciplinary context further shapes terminology. Broad sustainability concepts foreground transferable capabilities. Discipline-specific terms translate sustainability into professional practices such as chemistry, architecture, logistics, energy, and entrepreneurship. These are not competing definitions but points on a continuum from general sustainability competence to specialised capability. The appropriate level of specificity depends on educational purpose, disciplinary knowledge, professional practice, and the sustainability challenge that is to be addressed.

The pedagogical findings reinforce this contextual interpretation. Experiential and practice-based learning was the most frequently identified approach among the 13 studies reporting pedagogy. Experiential Learning Theory explains its emphasis on experience, reflection, conceptualisation, and experimentation (Kolb, 1984), while constructivism accounts for active meaning-making through authentic tasks (Biggs, 1996). Situated Learning Theory further explains the value of mentoring, student initiatives, professional contexts, and stakeholder engagement because competence develops through participation in relevant practices (Lave & Wenger, 1991).

Frequency should not be mistaken for effectiveness. Laboratory and structured interventions often provide more direct evidence of measurable outcomes. Coaching and experiential approaches more commonly capture engagement, reflection, behaviour, collaboration, or professional participation. Assessment needs to remain context-sensitive, as recent evidence shows substantial variation in the methods and instruments used to assess sustainability competencies (Sinakou & Daskolia, 2026). Technical programmes may emphasise observable performance; broader sustainability programmes may assess values, agency, or social action. Transformative Learning Theory is relevant to the latter because sustainability education can involve reconsidering professional responsibility, consumption, environmental justice, and societal change (Mezirow, 1991). The evidence supports pedagogical complementarity, and the six studies without identifiable pedagogy reveal a continuing implementation gap.

The six competency domains substantially correspond with established international sustainability frameworks through systems thinking, critical thinking, collaboration, strategic action, environmental responsibility, and sustainability action (Bianchi et al., 2022; United Nations Educational Scientific and Cultural Organization, 2017). The higher education evidence extends these models through stronger attention to technical expertise, employability, entrepreneurship, renewable energy, logistics, and digital sustainability. Green skills education, therefore, sits at the intersection of sustainability competence and professional competence. Digital sustainability further combines digital capability with systems thinking and environmental responsibility, although its limited representation in the corpus warrants cautious interpretation.

Conversely, anticipatory thinking, futures literacy, adaptability, fairness, political agency, and explicit engagement with competing sustainability values were less consistently operationalised than technical, behavioural, collaborative, and employability-related competencies. This may partly reflect the greater ease of embedding and measuring technical or behavioural outcomes. The imbalance suggests a need to examine how technical green skills can be combined with broader normative, future-orientated, and civic dimensions.

Institutional implementation was less consistently examined; only nine studies reported sufficiently explicit campus- or institution-level mechanisms. The corpus points to context-dependent pathways, not a universal model. European studies more visibly emphasised academic structures and student initiatives; African studies highlighted institutional support, interdisciplinary education, and development priorities; and several Asian studies focused on discipline- and profession-orientated implementation.

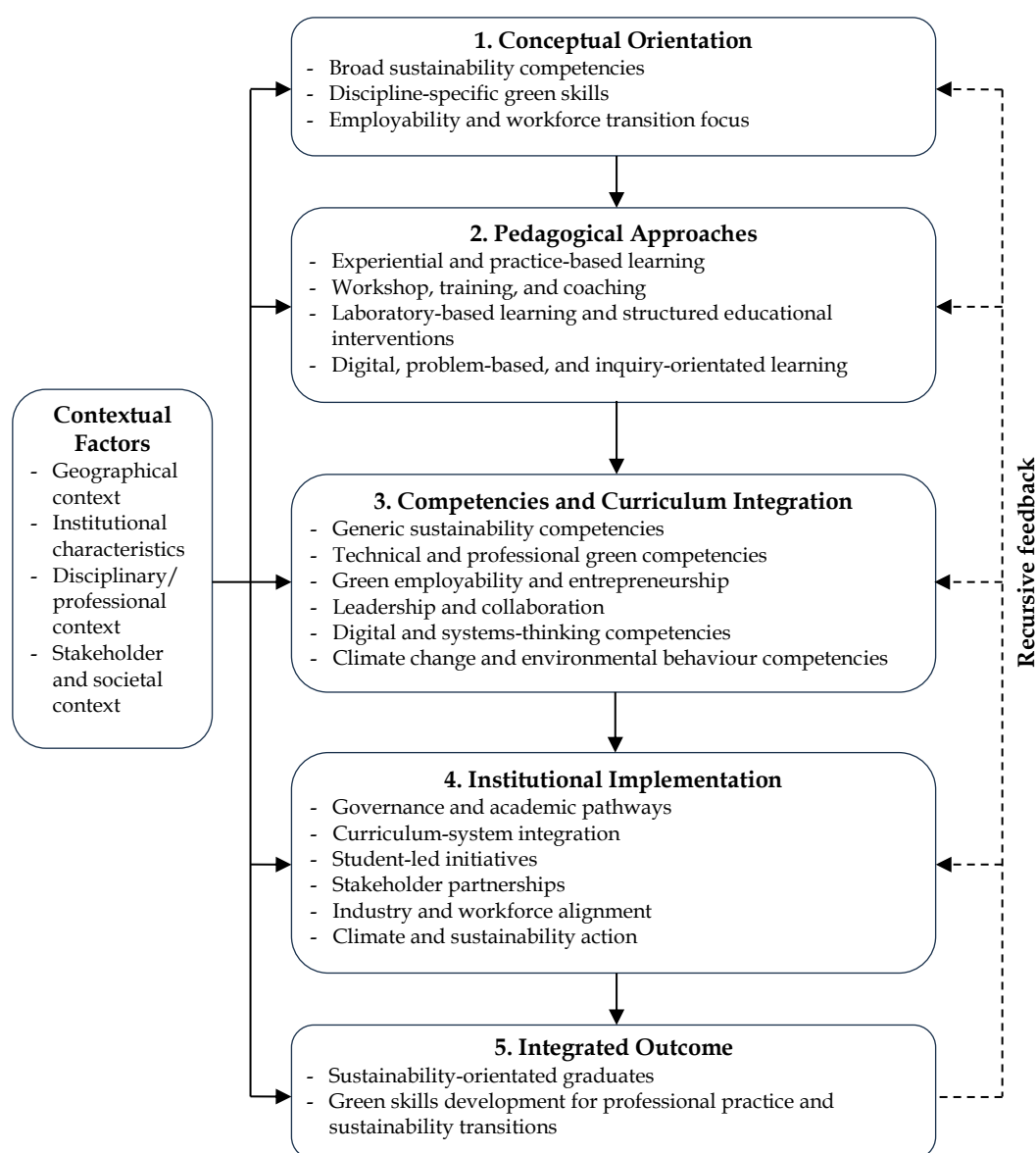
These patterns are not fixed regional characteristics but illustrate how institutional missions, disciplinary profiles, labour-market demands, socioeconomic priorities, and available support can enable or constrain implementation, which is consistent with recent evidence linking sustainability competencies to institutional operational and educational practices, curricular integration, and community engagement (Vargas-Merino & Vivanco Aquino, 2026).

Context helps explain contrasting implementation strategies. Some institutions embed sustainability through governance, culture, student engagement, and academic pathways. Others rely on specialised programmes, laboratories, disciplinary curricula, or workforce preparation. Neither is inherently superior. Whole-institution approaches can reinforce values and everyday practice; profession-orientated approaches can provide technical depth and occupational alignment. Campuses, communities, and industry partnerships can function as situated learning environments beyond the classroom.

The integrated framework synthesises these relationships without imposing a linear sequence. The four research questions defined the broad analytical domains, and inductive coding identified recurring categories and contextual variation. Cross-domain comparison showed that conceptual orientations correspond with different competency emphases; competencies are translated through pedagogy and curriculum, and institutional environments can reinforce or constrain implementation. Reciprocal influences and geographical, institutional, disciplinary/professional, and stakeholder/societal contexts are incorporated into Figure 2.

Figure 2 integrates conceptual orientation, pedagogical approaches, competencies and curriculum, and institutional implementation within contextual conditions. Reciprocal feedback indicates that curriculum, pedagogy, and institutional experience may reshape how green skills are conceptualised and prioritised; the arrows represent conceptual relationships, not causal or fixed temporal effects.

The framework complements established international sustainability frameworks by linking sustainability competency expectations with the educational and institutional processes through which they are developed (Bianchi et al., 2022; United Nations Educational Scientific and Cultural Organization, 2017). The empirical synthesis adds stronger attention to discipline-specific technical capabilities, employability and entrepreneurship, and emerging digital sustainability. Its contribution lies in connecting competency development with pedagogy, curriculum, institutional conditions, and wider professional or societal contexts; it does not depend on redefining individual competencies. This framing presents green skills development as a context-sensitive, recursive educational ecosystem that still requires empirical validation.



Note. Solid arrows indicate conceptual linkages; contextual arrows indicate cross-domain influences; and dashed arrows indicate reciprocal feedback. The arrows do not imply causal effects or a fixed temporal sequence.

Figure 2: Integrated framework of green skills development in higher education

6. Limitations

This review was restricted to English-language, peer-reviewed journal articles published between 2018 and 2024. Evidence outside this period and evidence in other languages or in conference proceedings, books, theses, institutional reports, policy documents, and grey literature may be missing, creating possible publication bias towards journal-based findings. The search covered Scopus, ProQuest, Emerald Insight, SAGE Journals, ScienceDirect, and supplementary Google Scholar searching, but no source captures all relevant literature. Google Scholar also has less standardised search and ranking procedures, which reduces reproducibility of that component.

The studies were heterogeneous in discipline, design, participants, conceptualisation, pedagogy, and outcome measures, thus limiting direct comparison and precluding meta-analysis. Evidence was also uneven across domains; 13 studies reported identifiable pedagogy and 9 recorded explicit institutional implementation. Consequently, the depth of synthesis varied across the four research questions. Quality appraisal and thematic coding were independently conducted by two reviewers. Both required interpretive judgement and disagreements were resolved by consensus. The six-item appraisal rubric supported consistency across heterogeneous designs but focused on general methodological transparency, adequacy, relevance, and reporting; it did not provide a design-specific risk-of-bias assessment. The integrated framework was derived from cross-study synthesis and was not directly tested. Hence, its relationships are conceptual, not validated causal effects, and require evaluation and refinement across higher education systems, disciplines, and institutional contexts.

Future research should address the uneven evidence across pedagogical and institutional domains through comparative, multi-institutional, and longitudinal studies examining how institutional type, discipline, policy, and resource capacity shape green skills development. A further priority is a more consistent measurement of curriculum outcomes and sustained competency development across settings. Digital green skills warrant particular attention, as artificial intelligence, data analytics, platforms, and automation reshape sustainability practice and professional work. Research should examine both how these technologies support learning, and which competencies are required for their environmentally and socially responsible use.

7. Conclusion

This systematic literature review synthesised 19 empirical studies published between 2018 and 2024 on how green skills are conceptualised, developed, integrated into curricula, and implemented in higher education. Green skills emerged as a multidimensional, context-dependent construct combining transferable sustainability competencies with discipline-specific technical and professional capabilities. Four interconnected dimensions structured the synthesis: conceptual orientation, pedagogical approaches, competencies and curriculum integration, and institutional implementation. Experiential and practice-based learning was the most frequently represented pedagogy. The

competency domains also covered employability, entrepreneurship, digital sustainability, climate action, and professional practice.

Institutional implementation varied across contexts, showing that curriculum, pedagogy, disciplinary needs, stakeholder engagement, and institutional priorities are interdependent. The framework brings these relationships together. The review is limited by its English-language, peer-reviewed scope, exclusion of grey literature, and heterogeneous study designs and outcomes, which restrict direct comparison of pedagogical effectiveness. In practice, the findings may inform institutional leaders considering green skills within strategic priorities, curriculum developers and educators aligning transferable and discipline-specific competencies, and higher education–industry partners developing authentic learning and workforce alignment.

Future research should prioritise longitudinal and cross-country studies, validate more consistent green skills measures, examine digital green skills, and empirically evaluate the framework across disciplines and institutions. By integrating conceptual, pedagogical, curricular, and institutional dimensions, the framework provides a synthesis-based foundation for coherent, context-sensitive green skills development in higher education.

Conflict of Interest

The authors declare no conflict of interest.

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9. Declaration of AI Use

The authors declare that Grammarly was used solely as an aid to improve the language and grammar of the paper. This paper remains an accurate representation of the authors' work and intellectual contributions.

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