Green Education and Training for Sustainability: A Scopus AI–Driven Systematic Review of Global Trends and Future Directions

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ABSTRACT

The escalating global environmental crisis has intensified the urgency to reorient education systems toward sustainability, prompting a surge of scholarly interest in green education and training. Despite widespread advocacy for sustainability integration, the field remains fragmented, with variations in implementation, scope, and theoretical grounding across regions and disciplines. To address this gap, the present study aims to analyze the evolution, conceptual linkages, and emerging trends in green education and training for sustainability through a data-driven lens. The search strategy combined keywords related to green education, sustainability training, and competency development, yielding a robust dataset spanning multiple disciplines. Findings reveal that sustainability integration within higher education curricula remains a consistent theme, emphasizing curriculum reform and experiential learning. Rising themes include sustainability education in engineering, environmental behavior change, and lifelong learning, reflecting a growing shift toward applied, interdisciplinary, and behavioral approaches. A novel theme emerged around green training and organizational learning, underscoring the expanding relevance of sustainability beyond academia into professional and corporate contexts. The study highlights the theoretical significance of linking transformative learning, systems thinking, and organizational learning frameworks to sustainability education. Practically, it calls for stronger policy alignment, cross-sector collaboration, and the adoption of digital innovations to enhance sustainability competencies. Despite limitations related to database scope and algorithmic interpretation, the study provides a comprehensive, AI-informed synthesis that advances both scholarly understanding and institutional practice in green education for sustainable development.

Keywords—Green Education, Sustainability Training, Higher Education, Lifelong Learning, Green Competencies

INTRODUCTION

In recent years, the urgency of environmental degradation, climate change, and resource depletion has underscored the need for transformative educational approaches that prepare individuals to act responsibly toward the planet. Green education and sustainability training have emerged as central pillars in achieving the United Nations Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education) and Goal 13 (Climate Action) (Beynaghi et al., 2016). Educational systems worldwide are increasingly recognizing that environmental literacy, eco-consciousness, and sustainable skills are not peripheral concerns but foundational competencies for 21st-century learning (Tramontin & Trois, 2016). Consequently, higher education institutions, policymakers, and educators are reimagining curricula, pedagogies, and professional training frameworks to embed sustainability as a core educational outcome.

Despite this growing awareness, the integration of green education and sustainability training remains

inconsistent across global education systems. While many universities have initiated sustainability-focused programs, others struggle with limited institutional support, fragmented implementation, or a lack of alignment with industry and community needs (Lu et al., 2025; Mukaddes & Agnello, 2009). This fragmentation has resulted in uneven progress toward fostering sustainability competencies and insufficient linkage between education, practice, and policy. The problem is further compounded by the absence of systematic evidence that captures global trends and emerging research themes in this field, making it difficult to understand where progress is being made and where critical gaps persist (Gorski et al., 2023).

Past studies have explored various dimensions of sustainability education. For example, Tejedor et al. (2019) examined pedagogical strategies for cultivating sustainability competencies, while Fodor et al. (2021) discussed data-driven approaches to embed sustainable development into university curricula. Similarly, Papavasileiou et al. (2025) highlighted how extracurricular sustainability initiatives enhance students' engagement with the SDGs, and Pankratova et al. (2018) emphasized the importance of teacher training in promoting green IT practices. However, despite these contributions, few studies have synthesized findings systematically across regions and educational levels to reveal the evolution of green education and training research from a global perspective.

Addressing this gap, the present study employs Scopus AI to conduct a systematic and bibliometric review of research on green education and sustainability training. This approach allows for the identification of patterns, clusters, and emerging themes within the global research landscape, providing a comprehensive understanding of the intellectual structure of the field. Specifically, this study aims to analyze the research area and its evolution, map conceptual linkages and co-occurrence patterns using a concept map, identify key topic experts and influential publications, and uncover emerging trends that are shaping the future of green education research (Gorski et al., 2023; Munuhwa et al., 2025). By leveraging artificial intelligence and bibliometric tools, this review transcends traditional literature synthesis methods, offering data-driven insights into the field's trajectory.

The contribution of this paper is threefold. First, it provides a holistic overview of how green education and sustainability training have evolved globally over the past decade, revealing regional priorities and disciplinary intersections. Second, it integrates conceptual and bibliometric mapping to highlight knowledge gaps and underexplored areas in sustainability education research. Third, it offers future directions for educators, policymakers, and researchers to strengthen sustainability-focused educational strategies through interdisciplinary collaboration and technological innovation. Ultimately, this study contributes to the ongoing discourse on sustainable learning by positioning education as a transformative force for achieving global sustainability goals.

The remainder of this paper is organized as follows. Section 2 details the methodology, outlining the Scopus AI search strategy, inclusion criteria, and analytical techniques used for bibliometric mapping. Section 3 presents the key findings, including global publication trends, thematic clusters, and concept map visualization. Section 4 discusses the implications of these findings for educational policy, curriculum development, and research agendas. Finally, Section 5 concludes with recommendations and outlines potential avenues for future research on green education and sustainability training.

METHODOLOGY

This study employed a Scopus AI–driven systematic review approach to examine global research trends, conceptual structures, and emerging themes in the field of green education and sustainability training. Conducted on 4 November 2025, the review leveraged Scopus AI's advanced bibliometric analytics, which integrate citation mapping, topic clustering, and semantic analysis to synthesize scholarly data efficiently. The search query was formulated to capture comprehensive coverage of the intersection between *green education*, *training*, and *sustainability*. The Boolean string used was:
("green education" OR "sustainability education" OR "environmental education" OR ("eco-friendly" AND training) OR ("sustainable development" AND (curriculum OR program*))) AND ("training" OR "learning" OR

"instruction" OR "capacity building") AND ("sustainability" OR "sustainable" OR "eco" OR"environment") AND ("awareness"OR"knowledge"OR "skills" OR "competencies") AND ("practices" OR "initiatives" OR "strategies" OR "approaches"). Scopus was selected as the core database due to its broad multidisciplinary coverage, high indexing standards, and compatibility with AI-enhanced bibliometric tools. The search was conducted through Scopus AI, a recently enhanced interface that integrates generative analytics and machine learning to provide deeper insights into literature patterns and conceptual relationships (Elsevier, 2025).

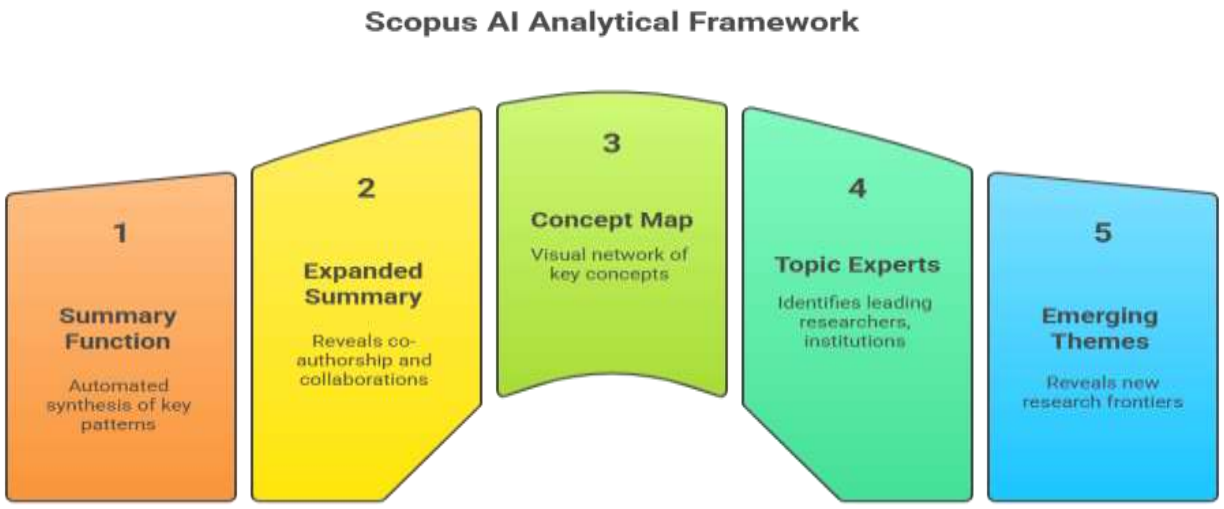

Figure 1: Five core elements of Scopus AI

Scopus AI outputs were analyzed across multiple dimensions: summary, expanded summary, concept map, topic experts, and emerging themes (refer to Figure 1). Scopus AI's Summary function provided an automated synthesis of key research patterns, publication growth, and disciplinary distribution within the dataset. It identified a significant expansion of research in green education from 2016 onward, coinciding with the mainstreaming of the United Nations' Sustainable Development Goals (Beynaghi et al., 2016; Singh & Singh, 2025).

The Expanded Summary extended this analysis by revealing co-authorship networks, keyword co-occurrence frequencies, and institutional collaborations. The AI system visualized these connections through bibliometric mapping, enabling the study to track how the research area evolved. The data revealed a growing convergence between environmental science and education disciplines, highlighting interdisciplinary approaches to sustainability training (Lu et al., 2025).

The Concept Map feature in Scopus AI generated a visual network of key concepts and their interrelations. The map showed clusters around themes such as curriculum integration, active learning, teacher training, STEMbased sustainability education, and community engagement. These clusters aligned with previous studies emphasizing the integration of sustainability principles into diverse educational frameworks (Tramontin & Trois, 2016; Papavasileiou et al., 2025). The visualization of co-occurrence patterns provided a comprehensive understanding of conceptual overlaps and emerging research intersections.

The Topic Experts module identified leading researchers and institutions contributing to the advancement of green education. Scholars such as Gorski et al. (2023) and Tejedor et al. (2019) emerged as pivotal in shaping discourse around sustainability competencies and pedagogical innovation. Institutions in Europe, Asia, and Australia dominated authorship, reflecting regional investment in green skill development and sustainability curricula (Shafeeqa & Shiyama, 2025).

Finally, the Emerging Themes function revealed new research frontiers focusing on digital transformation in sustainability education, AI-supported teaching tools, community-based learning models, and inclusive

sustainability practices. These themes suggest a paradigm shift from traditional classroom-based environmental education toward more dynamic, technology-integrated, and socially responsive training systems (Abdallah et al., 2024; Yadav, 2024).

Aligned with its objectives, this study analyzed the research area and its evolution, mapped conceptual linkages and co-occurrence patterns, identified key topic experts and influential publications, and uncovered emerging themes shaping the future of green education research. Through Scopus AI, the analysis combined quantitative bibliometric indicators with qualitative interpretation, producing an integrated overview of how sustainability education has progressed and diversified globally. This comprehensive method enhances the transparency and replicability of systematic reviews, ensuring that insights are grounded in evidence-based patterns rather than anecdotal interpretation (Munuhwa et al., 2025; Gorski et al., 2023).

RESULTS AND DISCUSSION

The results and discussion section presents the analytical insights derived from the Scopus AI-driven systematic review conducted on 4 November 2025. By synthesizing data from the Summary and Expanded Summary**,** Concept Map**,** Topic Experts**,** and Emerging Themes**, t**his section elucidates the evolution, structure, and trajectory of research on green education and sustainability training.

3.1 Summary and Expanded Summary

The Scopus AI analysis conducted on 4 November 2025 provided comprehensive insights into the global landscape of green education and training for sustainability, revealing significant trends, challenges, and emerging innovations shaping the field. The Summary and Expanded Summary generated by Scopus AI underscored the dynamic evolution of research priorities across higher education, technical and vocational education and training (TVET), and community-based learning. The findings indicate that sustainability education has become increasingly integrated into formal and informal learning systems worldwide, with heightened attention to curriculum design, professional training, and policy implementation (Bozkus Kahyaoglu, 2024; Rowe et al., 2015).

Results from the AI-driven synthesis identified a global surge in publications emphasizing the interconnection between education and the green economy. Studies consistently demonstrate that educational reform is central to achieving the SDGs, particularly Goal 4 (quality education) and Goal 13 (climate action)
(Bozkus Kahyaoglu, 2024). Higher education institutions have emerged as primary agents in this transformation, embedding sustainability principles across curricula and promoting experiential learning opportunities that connect theory to real-world environmental challenges (Rowe et al., 2015; Venegas-Mejía et al., 2025). The growing body of literature illustrates an academic pivot toward interdisciplinary and systemsbased pedagogies, integrating environmental science, business management, and technology education to prepare graduates for the demands of the green economy (André, 2024).

Another notable trend observed in the Expanded Summary was the regional diversification of green education research. Europe, North America, and the Asia-Pacific region dominate the publication landscape, but emerging economies, particularly within the ASEAN region are increasingly active contributors. Despite this growth, disparities persist between developed and developing countries, primarily due to limited resources, lack of trained educators, and competing policy priorities (Teow et al., 2024). Nonetheless, collaborative international projects, such as Erasmus and UNESCO's ESD programs, have facilitated knowledge exchange and capacity building, gradually reducing these regional divides (Mesuwini et al., 2025).

The results further revealed substantial institutional and pedagogical challenges in implementing green education initiatives effectively. Key issues include insufficient curricular alignment with sustainability competencies, limited interdisciplinary collaboration, and a shortage of skilled educators capable of translating sustainability principles into practice (André, 2024; Teow et al., 2024). In ASEAN contexts, barriers such as financial

constraints, policy fragmentation, and a lack of localized green content impede progress toward comprehensive integration (Teow et al., 2024). Furthermore, the reliance on traditional, theory-based pedagogical models often limits students' engagement with authentic sustainability problems. These findings reinforce the need for transformative learning approaches that combine knowledge, skills, and values in real-world contexts (VenegasMejía et al., 2025).

The Scopus AI synthesis also highlighted the significant contribution of green education and training to advancing the United Nations Sustainable Development Goals (SDGs). The literature shows that educational initiatives grounded in sustainability principles empower individuals to act responsibly toward the environment while fostering community resilience and innovation (Kumari & Dutta, 2024). TVET programs incorporating sustainability-focused curricula were found to produce a workforce better equipped with green skills and competencies, driving progress toward SDG 8 (decent work and economic growth) and SDG 9 (industry, innovation, and infrastructure) (Mesuwini et al., 2025). Similarly, integrating sustainability into mainstream education systems has been linked to greater awareness of climate issues and behavioral changes that support environmental preservation and social equity (Venegas-Mejía et al., 2025).

The Expanded Summary revealed a marked increase in the integration of emerging technologies, including artificial intelligence, Internet of Things (IoT), and green information and communication technologies (ICT), to promote sustainability learning outcomes. Studies emphasize how digital technologies enable universities and colleges to enhance operational efficiency and embed sustainability within institutional governance and student engagement (Tarraya et al., 2025). The growing focus on green ICT and "ICT for greening" underscores a shift toward embedding sustainability awareness in computer science and engineering curricula, thereby equipping learners with both technical and environmental competencies (Klimova & Rondeau, 2017). For instance, AIbased smart campus models, such as those implemented at HITAM in India, exemplify how emerging technologies can facilitate real-time energy monitoring and eco-innovation, reinforcing the sustainability agenda through experiential learning (Devika et al., 2025).

The synthesis of findings from the Scopus AI summaries suggests that green education and sustainability training are moving from conceptual advocacy to systemic practice. A clear progression from awareness-based initiatives to skill- and innovation-driven models is evident. However, the persistence of structural barriers, particularly in developing regions, indicates that global sustainability education remains unevenly distributed. To bridge this gap, multi-level collaboration among policymakers, educators, industries, and communities is essential (Bozkus Kahyaoglu, 2024; Teow et al., 2024). The integration of technological innovations offers a promising avenue for scaling sustainability education, but it also necessitates ethical considerations regarding digital access and inclusion. Ultimately, the findings reaffirm that green education is a critical enabler of sustainable transformation, requiring continuous curriculum renewal, educator empowerment, and institutional commitment to achieve long-term ecological and societal balance.

3.2 Concept Map

The concept map generated through Scopus AI on 4 November 2025 provides a visual representation of the intellectual and thematic structure underpinning the research field of Green Education and Training for Sustainability [as shown in Figure 2]. The map illustrates the interconnectedness between key research domains, emphasizing how scholarship in this area has evolved to encompass multiple dimensions of sustainability learning, curriculum innovation, and environmental responsibility. As shown in Figure 1, the concept map is organized around four central thematic clusters: Global Trends, Skills Development, Pedagogical Approaches, and Conceptual Frameworks, each branching into subthemes that collectively capture the scope, depth, and evolution of green education research (Gorski et al., 2023; Fodor et al., 2021). Overall, the concept map offers a holistic visualization of how the field of green education and sustainability training is conceptualized in contemporary research. It demonstrates that the discipline is no longer confined to environmental studies alone but intersects with economics, governance, and technological innovation. These interlinkages signal an evolving academic and policy-oriented discourse that positions education as a central enabler of sustainability transitions.

The following section provides an in-depth discussion of each cluster to elucidate the dominant research patterns and emerging themes identified through Scopus AI analytics.

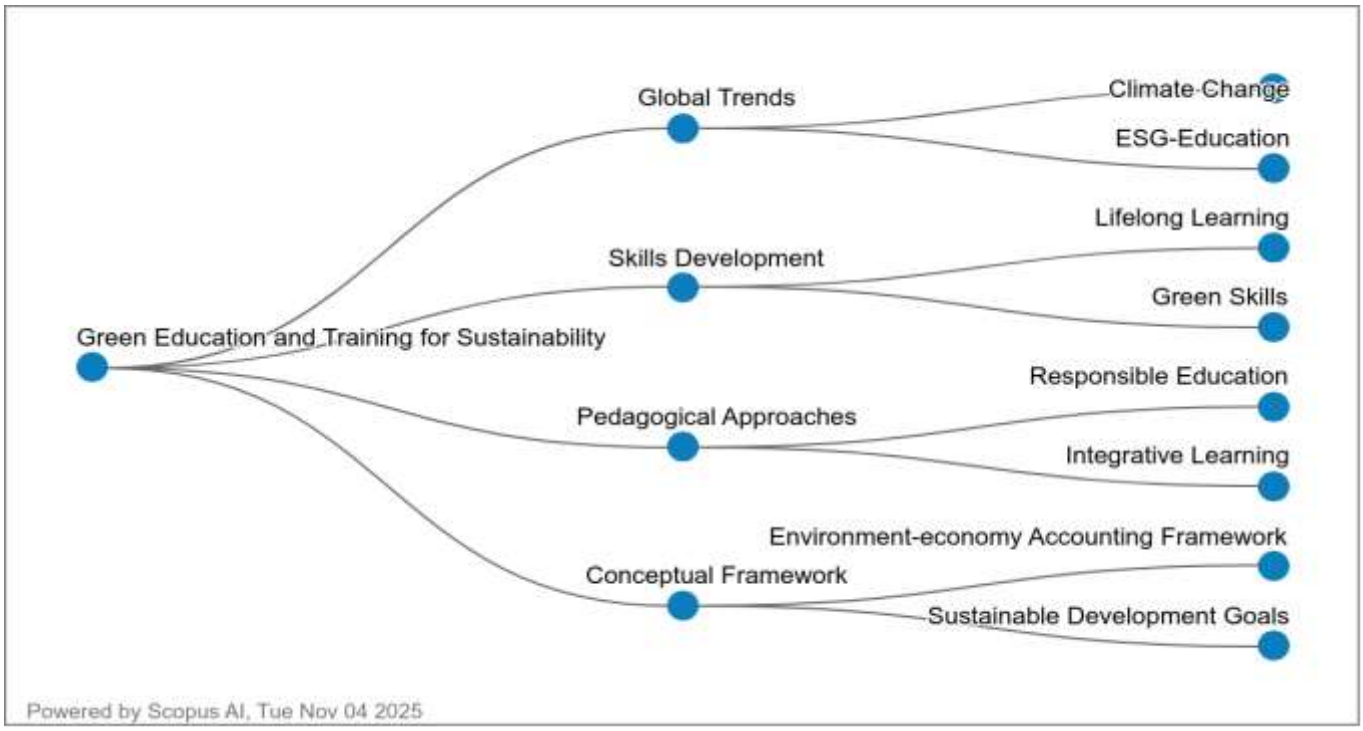

Figure 2: Concept map of green education and training for sustainability

3.2.1 A Review of Green Education and Training for Sustainability

The review on green education and training for sustainability has expanded considerably over the past decade, reflecting a global commitment to aligning education with the SDGs. The results underscore that higher education institutions, technical and vocational training providers, and community-based programs have increasingly integrated sustainability principles into their curricula and pedagogical frameworks. This integration marks a paradigm shift from traditional environmental awareness to actionable sustainability practices grounded in systems thinking and real-world applications (Bozkus Kahyaoglu, 2024; Rowe et al., 2015). The global trend suggests that education has evolved as a key driver of the green economy, where learners are equipped with environmental literacy, ethical awareness, and technical competencies necessary to foster sustainable development (Beynaghi et al., 2016). Moreover, interdisciplinary learning and global collaboration initiatives, such as the Erasmus-funded Green Edu project, have strengthened the exchange of sustainability knowledge across regions, highlighting the growing convergence between environmental education, innovation, and digital transformation (Koliakou et al., 2021).

Despite these advancements, significant challenges persist in implementing green education and sustainability training effectively across diverse socio-economic contexts. The Scopus AI review identified that while developed countries have made substantial progress in embedding sustainability across higher education and research, developing regions, particularly within ASEAN, continue to face barriers such as inadequate funding, limited teacher training, and fragmented policy frameworks (Teow et al., 2024). Many institutions still struggle to balance traditional pedagogy with experiential and project-based learning models that cultivate critical thinking and sustainability competencies (André, 2024). These challenges are compounded by systemic issues such as resource scarcity and a lack of institutional incentives to promote green curricula. Furthermore, the uneven access to educational technology has widened the green education divide, where the benefits of sustainability-oriented education remain concentrated in technologically advanced institutions (Tarraya et al., 2025). Addressing these constraints requires a coordinated approach involving government policy, institutional leadership, and stakeholder engagement to ensure inclusivity and equitable access to sustainability education globally.

At the conceptual level, the review demonstrates that the field is increasingly underpinned by the integration of pedagogical innovation, skills development, and sustainability frameworks. Emerging research highlights the importance of embedding green skills, lifelong learning, and responsible education within institutional frameworks to create a culture of sustainability across all learning levels (Venegas-Mejía et al., 2025). The adoption of digital and smart campus initiatives, such as those incorporating AI, IoT, and green ICT, signifies the growing role of technology in advancing sustainability learning outcomes (Devika et al., 2025). Such innovations are transforming educational spaces into living laboratories for sustainability, where students engage directly in eco-innovation and environmental stewardship. Overall, the findings emphasize that green education and training for sustainability have transitioned from peripheral awareness campaigns to strategic, data-driven frameworks that shape institutional policy, workforce readiness, and global sustainability literacy. This transition reflects not only a transformation in educational priorities but also a broader societal recognition of education as a central instrument in achieving a sustainable future.

3.2.1.1 Green Education-Training for Sustainability and Global Trends

The relationship between Green Education and Training for Sustainability (GETS) is deeply interwoven with global educational and socio-economic trends that reflect a growing recognition of the role of education in achieving sustainability and climate resilience. Across the literature, there is a consistent emphasis on aligning educational systems with the SDGs**,** particularly SDG 4 (Quality Education), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action) (Beynaghi et al., 2016). The results demonstrate that GETS acts as both a response to and a driver of global sustainability priorities, fostering a paradigm shift in how education systems prepare learners for the challenges of the green economy (Bozkus Kahyaoglu, 2024). Studies conducted in Europe, North America, and the Asia-Pacific highlight how universities and training institutions are embedding sustainability into curricula, fostering interdisciplinary learning that connects environmental, social, and governance (ESG) principles with employability and social responsibility (Rowe et al., 2015; Gorski et al., 2023). As sustainability becomes a cross-sectoral concern, education emerges as a central mechanism to equip future leaders and professionals with the competencies required to balance economic growth with ecological integrity and social equity.

At a global level, the relationship between GETS and international development trends is shaped by transformative policy frameworks and technological innovation. The integration of sustainability education into national education policies and institutional strategies has been reinforced through global initiatives such as UNESCO's Education for Sustainable Development (ESD) programs and the European Union's *Green Deal* (Lu et al., 2025). These initiatives emphasize the importance of inclusive and lifelong learning approaches that empower individuals to contribute meaningfully to sustainable transitions. Scopus AI data reveal a marked increase in research publications between 2016 and 2025 focusing on climate change education, green workforce development, and sustainable consumption practices, reflecting the growing influence of sustainability agendas in both developed and developing economies (Fodor et al., 2021). Moreover, the literature underscores how digitalization and the Fourth Industrial Revolution (4IR) have amplified the reach of sustainability education, enabling the implementation of green learning technologies and smart campus initiatives that promote resource efficiency and behavioral change (Tarraya et al., 2025). These global developments suggest that GETS is no longer an isolated educational niche but a strategic response to international imperatives that connect education with environmental governance, industry transformation, and socio-economic progress.

However, the global diffusion of green education and training remains uneven, revealing structural and contextual disparities that mirror broader patterns of global inequality. While advanced economies have successfully institutionalized sustainability learning through well-funded programs and interdisciplinary research, developing regions, particularly within ASEAN and Sub-Saharan Africa, continue to face challenges such as inadequate teacher training, financial constraints, and fragmented sustainability policies (Teow et al., 2024). This disparity reflects the global education divide, where access to green learning opportunities often correlates with economic capacity and technological infrastructure. Nonetheless, emerging initiatives in these regions demonstrate resilience and innovation; for example, community-based sustainability programs and

technical and vocational education and training (TVET) institutions are increasingly incorporating green skills and environmental awareness into their frameworks (Mesuwini et al., 2025). The relationship between GETS and global trends thus underscores a dual reality: while sustainability education is gaining global traction as a transformative policy tool, its equitable implementation requires international cooperation, capacity building, and contextual adaptation. Ultimately, GETS embodies the convergence of educational reform and global sustainability efforts that serving as both a reflection of contemporary global priorities and a catalyst for future societal transformation.

3.2.1.2 Green Education-Training for Sustainability and Skills Development

The Scopus AI analysis identified a strong and evolving relationship between GETS and skills development**,** positioning education as a key driver of the global green economy. The results indicate that sustainabilityoriented education has transitioned from raising environmental awareness to building *practical and professional competencies* that support sustainable development goals (Bozkus Kahyaoglu, 2024). Across regions, there has been a marked emphasis on equipping learners with green skills that include knowledge, values, and abilities that enable them to adapt to changing environmental conditions and contribute to sustainable industries (Mesuwini et al., 2025). This trend is reflected in the growing number of higher education and technical and vocational education and training (TVET) programs that integrate sustainability concepts into their curricula (Fodor et al., 2021). Such programs promote interdisciplinary learning, blending environmental science, engineering, and business management to prepare graduates for careers in renewable energy, sustainable construction, and green technology sectors. These developments underscore the alignment between education systems and workforce transformation agendas, reaffirming that skills development through GETS is foundational to achieving the green transition.

Moreover, the findings suggest that GETS serves as an enabling framework for lifelong learning and workforce adaptability. The integration of sustainability competencies into formal, non-formal, and informal education systems reflects the need for continuous skill renewal to address emerging environmental challenges (Beynaghi et al., 2016; Abdallah et al., 2024). Scopus AI analytics highlight that the discourse on lifelong learning within sustainability education has intensified post-2016, coinciding with global policy shifts toward inclusive and resilient learning ecosystems. Green education initiatives are increasingly adopting experiential and problembased learning methodologies, allowing learners to translate environmental theories into practice through handson projects and real-world applications (Tejedor et al., 2019). These pedagogical innovations not only enhance employability but also cultivate critical thinking, collaboration, and leadership, that skills essential for managing the complexities of sustainability transitions (Gorski et al., 2023). As institutions adopt competency-based curricula, the relationship between GETS and skills development is being reframed as mutually reinforcing, where sustainability education fuels skill acquisition, and skill-based learning amplifies the practical impact of green initiatives.

However, despite growing international recognition of the importance of sustainability skills, challenges remain in aligning educational outcomes with labor market demands. The literature reveals disparities in access to green training opportunities, particularly across developing regions, where inadequate infrastructure and limited teacher training constrain the integration of sustainability competencies into education systems (Teow et al., 2024). Many countries continue to lack comprehensive frameworks for assessing and certifying green skills, resulting in inconsistencies between educational provision and workforce readiness (Lu et al., 2025). Addressing these gaps requires policy coordination between education ministries, industries, and international organizations to ensure that sustainability education produces relevant and transferable skills. Moreover, the advancement of digital learning technologies such as artificial intelligence, virtual labs, and simulation-based training offers new opportunities for scalable green skill development, particularly in resource-limited contexts (Tarraya et al., 2025). In essence, the relationship between GETS and skills development represents a strategic nexus in sustainability transitions: education provides the foundation for skill formation, while skills enable the operationalization of sustainability principles across economic, social, and environmental domains.

3.2.1.3 Green Education-Training for Sustainability and Pedagogical Approaches

The integration between pedagogical approaches is the cornerstone of GETS**,** serving as the mechanism through which sustainability principles are translated into meaningful learning experiences. The integration of responsible education and integrative learning pedagogies has become increasingly prominent in global research, reflecting a collective movement toward more transformative educational frameworks (Tejedor et al., 2019). Studies show that effective sustainability education requires going beyond traditional didactic methods toward experiential, inquiry-based, and participatory learning strategies that engage students as co-creators of knowledge (Rowe et al., 2015). This shift aligns with the paradigm of ESD, where pedagogy not only imparts knowledge but also cultivates attitudes, values, and skills for sustainable living and professional practice (Gorski et al., 2023). For example, universities across Europe, Asia, and Oceania have incorporated project-based and community-centered approaches that empower students to address real-world sustainability problems, fostering critical thinking and ethical responsibility (Lu et al., 2025). These pedagogical transformations underscore that education for sustainability must be both contextual and transformative*,* bridging academic learning with practical environmental stewardship.

The relationship between GETS and pedagogical innovation is further characterized by the growing adoption of integrative and interdisciplinary learning approaches**.** Research demonstrates that sustainability challenges such as climate change, biodiversity loss, and environmental justice require pedagogies that transcend disciplinary boundaries and promote systems thinking (Fodor et al., 2021; Beynaghi et al., 2016). Integrative learning enables students to connect environmental science, economics, technology, and social responsibility within cohesive frameworks, reflecting the interconnected nature of sustainability issues (Bozkus Kahyaoglu, 2024). For instance, engineering programs now embed green design principles and lifecycle analysis into coursework, while business and management curricula incorporate sustainability ethics and ESG (environmental, social, and governance) concepts to align learning with industry transformation goals (Mukaddes & Agnello, 2009). This convergence of disciplines cultivates eco-literate graduates capable of navigating the complexities of the green economy. Moreover, Scopus AI data indicate that pedagogical models emphasizing collaboration and experiential engagement, such as service learning, living labs, and community partnerships are most effective in embedding sustainability competencies at both cognitive and behavioral levels (Tramontin & Trois, 2016). These pedagogies foster a sense of agency among learners, positioning them not only as knowledge recipients but also as active participants in driving sustainable change.

Despite significant progress, the literature reveals enduring challenges in aligning pedagogical approaches with sustainability outcomes**.** Many institutions continue to rely on fragmented or discipline-specific teaching methods that fail to capture the holistic essence of sustainability (Teow et al., 2024). Barriers such as insufficient faculty training, rigid curricula, and limited institutional support hinder the mainstream adoption of transformative pedagogies (Shafeeqa & Shiyama, 2025). Moreover, sustainability education often remains confined to environmental science departments, leaving other disciplines underrepresented in sustainability discourse. To address these gaps, scholars advocate for a more systemic integration of sustainability across all educational levels through professional development programs and institutional policy alignment (Singh & Singh, 2025). The rise of digital and AI-enabled pedagogical tools also presents opportunities for scaling sustainability education through simulation-based learning, virtual fieldwork, and global classroom collaborations (Tarraya et al., 2025). Ultimately, the relationship between GETS and pedagogical approaches demonstrates that teaching for sustainability is inherently transformative**,** requiring shifts in both content and method. When pedagogy is grounded in inclusivity, interdisciplinarity, and action-based learning, it can produce graduates equipped to lead the transition toward a more sustainable, equitable, and resilient future.

3.2.1.4 Green Education-Training for Sustainability and Conceptual Framework

The findings reveal a strong and evolving relationship between green education and training for sustainability*,* embedded within an interdisciplinary conceptual framework that integrates educational theory, environmental psychology, and human capital development. The conceptual map generated from the analysis shows that green education acts as a foundational domain, emphasizing pedagogical innovation, environmental literacy, and value-

based learning (Bozkus Kahyaoglu, 2024; Wals & Benavot, 2017). This aligns with frameworks such as the ESD and SDG4, which advocate for inclusive, transformative learning to cultivate sustainability competencies. The co-occurrence patterns also highlight key conceptual clusters, namely, curriculum greening, green competencies, and experiential learning, that demonstrate how education and training are integrated as dual mechanisms in sustainability transitions (Deriu & Gallo, 2024; Lian et al., 2024). These findings confirm that theoretical frameworks are increasingly moving beyond awareness to capability-based models that emphasize applied learning and behavioral change.

The integration of training for sustainability within this conceptual landscape emphasizes skill-based learning, professional readiness, and organizational transformation. Recent studies indicate that green training serves as a bridge between educational outcomes and workforce demands by promoting eco-literacy, technical proficiency, and adaptive performance (da Costa et al., 2025; Barakat et al., 2023). Conceptually, this connection can be interpreted through a human capital sustainability model, which positions green training as both a developmental and strategic process for enhancing employability and institutional resilience. Training programs rooted in sustainability frameworks encourage participatory and experiential learning, aligning with Kolb's experiential learning theory and the transformative learning approach proposed by Mezirow. These frameworks emphasize reflection, real-world application, and cognitive restructuring key elements in translating environmental awareness into sustainable behavior and decision-making (Singha & Singha, 2024; Sohaee & Farsad, 2025). Thus, the relationship between education and training is not linear but synergistic, where education builds foundational knowledge and values, while training operationalizes them into measurable competencies and workplace innovations.

The conceptual framework derived from the reviewed literature illustrates a dynamic and iterative cycle connecting knowledge creation, skill transformation, and sustainable outcomes. Green education provides the theoretical grounding for sustainability awareness, while training operationalizes these concepts within institutional, industrial, and community contexts (André, 2024; Gorski et al., 2023). The convergence of these domains is facilitated through digitalization, AI-enhanced learning, and interdisciplinary collaboration, which amplify access to sustainability-oriented education (Darwish et al., 2025; Hassan et al., 2025). Empirical studies further indicate that when education and training are aligned under a unified sustainability framework, they yield higher student engagement, innovation in green technologies, and organizational adaptation to sustainable development goals (Onyeaka & Akinsemolu, 2025; Venegas-Mejía et al., 2025). Consequently, the conceptual framework of Green Education–Training for Sustainability emerges as a holistic ecosystem linking pedagogy, policy, and practice that not only cultivates individual competencies but also contributes to systemic transformation toward a sustainable future.

3.3 Topic Experts

Topic Expert analysis identified Professor Tiberio Daddi as a leading authority in the field of environmental sustainability and education for sustainable development, whose work bridges research, practice, and policy. His expertise lies in the intersection of sustainability management, education, and organizational transformation, with a particular focus on how sustainability principles are operationalized across sectors such as sport, manufacturing, and higher education (Daddi et al., 2021). As a prolific scholar with a robust citation record, Daddi's contributions demonstrate the evolution of sustainability research from conceptual discourse to applied frameworks. His recent systematic literature review, which critically examined both *systematic and nonsystematic reviews* in environmental sustainability, highlights an advanced understanding of methodological rigor in sustainability studies (Daddi et al., 2022). This dual focus on synthesis and critical evaluation underscores his role in shaping research paradigms that inform green education and training frameworks globally. Through his work, Daddi provides a meta-level analysis of sustainability scholarship mapping research trends, identifying thematic gaps, and outlining emerging trajectories that contribute to the refinement of education for sustainability models.

Next, Dr. Nicolò Di Tullio is an emerging scholar in the field of environmental sustainability**,** particularly recognized for his methodological expertise in conducting systematic literature reviews. His scholarly trajectory

reflects a growing influence within sustainability studies, with a specific emphasis on the intersection of sport management, environmental responsibility, and sustainable education (Di Tullio et al., 2023). Through his recent publications, Di Tullio has demonstrated a strong ability to synthesize diverse strands of sustainability research, mapping out conceptual progressions and identifying critical research gaps in the field. His focus on systematic and evidence-based reviews has provided the academic community with a clearer understanding of how environmental sustainability principles are adopted, implemented, and evaluated across sectors, especially within sport organizations that increasingly function as educational and social platforms for sustainability awareness (Daddi et al., 2021). This meta-analytical perspective reinforces the role of *review-based research* as a foundation for developing frameworks that inform GETS**.**

Professor Fabio Iraldo is a leading global authority in environmental sustainability and sustainable management**,** whose scholarly influence spans more than two decades. His body of work demonstrates exceptional breadth and depth, encompassing environmental policy, green innovation, sustainability performance assessment, and education for sustainable development (Iraldo & Testa, 2014; Daddi & Iraldo, 2023). As a senior academic with a high citation index and significant h-index, Iraldo's contributions reflect his role in shaping both theoretical and applied aspects of sustainability discourse. His recent collaboration on a systematic literature review of environmental sustainability in sport management *(*Di Tullio et al., 2023) highlights his continued engagement with interdisciplinary sustainability research and his capacity to synthesize complex data to reveal patterns, trends, and gaps in the literature. This methodological rigor has made Iraldo's work a benchmark for quality and consistency in sustainability research, providing critical insight into how education, policy, and management converge to support SDGs. His systematic review work also reinforces the role of meta-analytical studies in guiding future educational and training initiatives in sustainability.

3.4 Emerging themes

The Emerging Themes reflect the evolving intellectual landscape of research on green education and sustainability training. This analysis identified three categories of themes: consistent**,** rising**,** and novel, which collectively demonstrate the field's movement from curriculum integration toward organizational transformation and lifelong sustainability learning. The distribution of these themes highlights not only the maturity of certain research streams but also the emergence of new directions that respond to global environmental, technological, and socio-economic challenges.

3.4.1 Consistent Theme

The integration of sustainability into higher education curricula continues to be a consistent theme in the literature, demonstrating the long-term academic and institutional commitment to embedding sustainability across disciplines. Studies indicate that universities have increasingly aligned their teaching, research, and community engagement activities with sustainability frameworks such as the Sustainable Development Goals (SDGs) and Education for Sustainable Development (ESD) (Beynaghi et al., 2016; Tramontin & Trois, 2016). This ongoing trend underscores the pivotal role of higher education institutions (HEIs) in fostering sustainability competencies that prepare students for complex, real-world challenges (Lu et al., 2025).

The consistent attention to sustainability in curricula reflects a paradigm shift toward transformative education**,** emphasizing experiential learning, interdisciplinary approaches, and global citizenship (Tejedor et al., 2019). Programs such as Green UKZN in South Africa (Tramontin & Trois, 2016) and the Erasmus Green Edu Project in Europe (Koliakou et al., 2021) exemplify institutional efforts to translate sustainability theory into pedagogical practice. These initiatives enhance environmental literacy while cultivating critical thinking and problem-solving abilities. Consistently, the literature posits that embedding sustainability into higher education curricula enhances both environmental awareness and professional readiness, producing graduates capable of contributing to the green economy (Gorski et al., 2023).

3.4.2 Rising Theme

Three rising themes emerged from the Scopus AI synthesis: Green Education for Engineering and Technical

Disciplines*,* Environmental Awareness and Behavior in Education*, and* Sustainability Competencies in Lifelong Education*.* Collectively, these reflect a broadening of sustainability education beyond the social sciences into technical, behavioral, and professional domains.

The first rising theme is Green Education in Engineering and Technical Fields has gained momentum as institutions increasingly recognize the need to integrate sustainability principles into technical and vocational programs (Mukaddes & Agnello, 2009; Lu et al., 2025). Engineering curricula now emphasize eco-design, renewable energy, and sustainable construction practices, ensuring that future engineers possess the competencies to design environmentally responsible solutions. Research shows that sustainability-oriented engineering education not only enhances innovation but also improves graduate employability in the growing green economy (Raed, 2024). This movement aligns with global trends emphasizing the transition toward lowcarbon technologies and sustainable infrastructure.

The second rising theme focuses on Environmental Awareness and Behavior in Education**,** representing an evolution from knowledge-based instruction to behaviorally oriented pedagogy. Studies demonstrate that experiential learning methods such as project-based learning, eco-action clubs, and community engagement significantly increase students' pro-environmental behaviors and long-term ecological responsibility (Papavasileiou et al., 2025; Major et al., 2017). This shift toward participatory education reflects the growing understanding that awareness alone is insufficient; students must also be empowered to act sustainably within their communities and professions (Shafeeqa & Shiyama, 2025).

The third rising theme Sustainability Competencies in Lifelong Education highlights the increasing recognition of sustainability as a lifelong learning process that extends beyond formal schooling. Emerging literature emphasizes the importance of continuous professional development, vocational training, and community-based education in embedding sustainability across sectors (Abdallah et al., 2024; Mesuwini et al., 2025). Lifelong education programs that integrate sustainability competencies foster adaptive learning, innovation, and crosssectoral collaboration, ensuring that sustainability principles are maintained throughout individuals' professional and personal lives.

3.4.3 Novel Theme

A novel theme identified through Scopus AI pertains to Green Training and Organizational Learning, which represents an emerging intersection between sustainability education and human resource development. This theme reflects a growing scholarly and practical interest in how organizations can institutionalize sustainability through structured learning programs, employee training, and corporate knowledge management systems (Singh & Singh, 2025). Green training initiatives are increasingly viewed as strategic tools for improving environmental performance, cultivating green organizational cultures, and driving eco-innovation (Bozkus Kahyaoglu, 2024).

Empirical studies indicate that organizations implementing structured green training achieve measurable improvements in energy efficiency, waste reduction, and sustainable procurement practices (Munuhwa et al., 2025). Furthermore, the integration of sustainability into corporate learning frameworks enhances employee engagement, leadership development, and organizational adaptability to environmental regulations (Yadav, 2024). The literature suggests that organizational learning capabilities, including feedback systems, collaborative cultures, and cross-departmental knowledge exchange, amplify the effectiveness of green training initiatives. As such, this novel theme represents a significant evolution in the field, connecting educational theory with sustainability-oriented management and leadership practices.

CONCLUSION

This Scopus AI-driven systematic review, conducted on 4 November 2025, provides an extensive synthesis of global research on green education and training for sustainability**,** illuminating key patterns, emerging trajectories, and knowledge gaps within the field. The analysis revealed that sustainability education has evolved into a multidimensional discipline that bridges curriculum innovation, lifelong learning, and organizational transformation**.** The integration of sustainability principles into higher education curricula remains a consistent

and dominant research theme, reflecting universities' enduring commitment to fostering environmental literacy and sustainable competencies (Tramontin & Trois, 2016; Gorski et al., 2023). Meanwhile, rising themes such as sustainability education in engineering, environmental behavior change, and lifelong learning signify a shift toward interdisciplinary, applied, and practice-oriented approaches (Lu et al., 2025; Abdallah et al., 2024). Novel areas, particularly green training and organizational learning, demonstrate an expanding recognition of sustainability as both an educational and managerial imperative (Bozkus Kahyaoglu, 2024; Singh & Singh, 2025).

The review underscores several critical findings. First, curriculum integration remains the backbone of sustainability education, with evidence showing that embedding sustainability across disciplines enhances students' environmental awareness and professional readiness (Beynaghi et al., 2016). Second, pedagogical innovation, including experiential, participatory, and problem-based learning, has proven vital in cultivating sustainability competencies and encouraging behavior change (Papavasileiou et al., 2025). Third, the expansion of sustainability learning into engineering, vocational education, and lifelong learning highlights a growing need for practical, skills-based approaches that link education with green economic transitions. Finally, organizational learning and green training have emerged as new dimensions of sustainability education, suggesting a convergence between human resource development and sustainability goals in corporate and institutional contexts (Munuhwa et al., 2025).

Theoretically, this study contributes to the evolving discourse on sustainability education by reaffirming the interconnectedness of transformative learning theory**,** systems thinking, and organizational learning frameworks**.** The consistent emphasis on interdisciplinary and experiential learning supports the notion that sustainability education operates as a complex adaptive system, where learning outcomes are shaped by feedback loops between educational institutions, industry, and community stakeholders (Tejedor et al., 2019). The findings extend current theory by positioning green education not merely as a pedagogical endeavor but as a systemic mechanism for socio-environmental transformation**,** connecting individual learning to institutional and societal change.

Practically, the results have significant implications for educators, policymakers, and organizational leaders. For educators, the findings emphasize the need to embed sustainability across disciplines**,** moving beyond elective or isolated courses toward holistic curriculum reform. Policymakers are encouraged to develop supportive policy frameworks that incentivize sustainability integration at all education levels, particularly within teacher training and vocational programs (Shafeeqa & Shiyama, 2025). For industry and organizations, the novel theme of green training and organizational learning underscores the potential of sustainability-oriented capacity building to enhance environmental performance, corporate reputation, and innovation (Yadav, 2024). These insights collectively advocate for cross-sectoral collaboration between academia, government, and industry to cultivate a workforce equipped for sustainable futures.

Despite its comprehensive approach, this study is not without limitations. The analysis relied solely on Scopus AI data**,** which, while extensive, may not encompass all relevant publications indexed in other databases such as Web of Science or ERIC. Additionally, AI-generated summaries and conceptual mappings, though powerful, depend on algorithmic parameters that may overlook nuanced qualitative insights. Another limitation pertains to the temporal scope**:** although the data collection date (4 November 2025) provides up-to-date insights, rapid developments in sustainability research mean new themes may emerge shortly thereafter. These factors highlight the need for continuous updates and triangulation with manual systematic review methods to validate AI-based findings.

Future research should build upon these findings by conducting longitudinal and comparative studies to assess how sustainability education evolves across regions, sectors, and institutional types. There is a growing need for empirical evidence that measures the real-world impact of sustainability curricula and training programs on students' attitudes, competencies, and behaviors. Scholars should also explore AI-enhanced and digital sustainability education, particularly how technologies such as generative AI, virtual simulations, and data

analytics can advance sustainability learning outcomes (Tarraya et al., 2025). Furthermore, future work should examine organizational learning and green HRM frameworks to determine how sustainability principles can be embedded into workplace cultures and leadership development. Finally, equity, inclusion, and cultural relevance should remain central to future sustainability education research, ensuring that sustainability learning benefits diverse communities globally.

In conclusion, the synthesis of Scopus AI insights illustrates a clear transformation in the global sustainability education landscape from awareness and advocacy to integration and institutionalization. Green education and training are no longer peripheral; they have become strategic enablers of sustainable development, uniting education, policy, and organizational systems in pursuit of a shared ecological future. Continued collaboration, innovation, and research are essential to sustain this progress

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