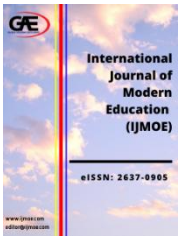
International Journal of Modern Education
EISSN: 2637-0905
Volume: 8 Issue: 32 (December 2026) PP. 86-104



INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.gaexcellence.com/ijmoe

GREEN INNOVATION IN SCHOOL SUSTAINABILITY FOR SUSTAINABLE DEVELOPMENT GOAL 12: A HISTORICAL REVIEW (2015-2026)

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Article Info:

Article history:
Received date: 28.09.2026
Revised date: 13.10.2026
Accepted date: 03.11.2026
Published date: 01.12.2026

To cite this document:

Osman, N., Khairani, A. Z., & Mustafa, W. A. (2026). Green Innovation in School Sustainability for Sustainable Development Goal 12: A Historical Review (2015-2026). *International Journal of Modern Education, 8*(32), 86-104.

Abstract:

Green innovation has emerged as an increasingly important pathway for advancing school sustainability by integrating environmental technologies, sustainable practices, educational processes, and institutional transformation. However, the evolution of research on green innovation in school sustainability remains fragmented, with limited understanding of how research priorities have developed over time. This study therefore examines the historical development and thematic evolution of green innovation research within the context of school sustainability from 2015 to 2026. A systematic advanced search was conducted using the Scopus database through a structured combination of the main keywords *green innovation*, *school*, and *sustainability*, resulting in a final primary dataset of 97 publications. The selected studies were analysed chronologically and clustered into three temporal phases according to publication trends and the evolution of research findings. Phase 1, the Emergence and Foundation Phase (2015–2018), comprised studies establishing the technological, behavioural, infrastructural, and educational foundations of green innovation in schools. Phase 2, the Consolidation and Transitional Phase (2019–2022), demonstrated increasing integration of green innovation with leadership, green skills, experiential learning, institutional capacity, circular practices, and environmental performance. Phase 3, the Acceleration and Expansion Phase (2023–2026), represented the most diversified stage, characterised by stronger emphasis on curriculum integration, digital and green technologies,

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environmental leadership, partnerships, teacher and student competencies, and system-level sustainability. Notably, publication output peaked at 20 studies in 2025, before declining to 17 studies in 2026, while the thematic scope became increasingly systemic and transformative. Overall, the findings demonstrate a clear chronological shift from technology-oriented and infrastructure-based interventions towards integrated socio-technical and institutional approaches, positioning schools not merely as sites for implementing green technologies but as dynamic ecosystems for cultivating competencies, innovation, collaboration, and long-term sustainability.

DOI: 10.35631/IJMOE.832005

Keywords:

Green Innovation, School Sustainability, SDG 12

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Introduction

Green Innovation in School Sustainability: A Historical Review

Green innovation has become an essential pathway to advancing school sustainability by integrating environmental technologies, sustainable practices, educational processes, and institutional transformation. The transition to more sustainable development faces constant challenges. The effort towards school sustainability focuses on environmental impacts, including the development and adoption of environmentally oriented products, services, processes, and practices that incorporate novelty (Qin et al., 2025; Guinot et al., 2022). Due to the growth in environmental awareness and increasing demand for sustainable practices, research on green innovation has expanded substantially (Takalo et al., 2021). Bibliometric evidence indicates a marked increase in research on innovation and sustainability, reflecting a stable growth of the field and reaching a professional level of development across sectors (Maier et al., 2020).

There has been a steady growth in green innovation research from 2011 to 2018. Publication of articles in conjunction with school sustainability can be seen in top-ranked journal outlets, and empirical quantitative surveys dominated the methodological landscape (Oduro et al., 2021). However, research principally focuses on the Porter hypothesis and the resource-based view, and the field lacks the adoption and development of novel theories (Oduro et al., 2021). Sustainability-oriented innovation not only derives from its products, processes, or practices but also involves making intentional changes to an organization's philosophy and values. It paves the way to create and realize social and environmental value in addition to economic returns. A critical review of the literature reveals limited attention to sustainability-oriented innovation, with persistent gaps in its definition, conceptualization, measurement, and alignment with contemporary practices. Moreover, existing research still has several weaknesses, especially in defining what sustainability-oriented innovation means, explaining

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its conceptual framework, measuring it systematically, and ensuring that the concept reflects current sustainability practices.

Green innovation in schools should be understood as a multidimensional concept encompassing not only environmental technologies but also sustainable organizational values, practices, processes, and capabilities. Previously, green innovation was often understood mainly as environmentally friendly technologies, such as renewable energy, recycling technologies, energy-efficient equipment, or pollution-control systems. However, newer research recognizes that green innovation is not limited to technology. This development has also widened the understanding of sustainability-oriented innovation beyond environmental technologies to include organizational values, processes, practices, and capabilities that generate environmental and social value alongside economic outcomes (Cillo et al., 2019). It can also involve organizational values where schools may develop a culture that prioritizes sustainability. It may also result in changing how activities are carried out, for example to reduce waste or resource consumption. Practices may include adopting sustainable everyday practices, such as recycling, energy conservation, and responsible consumption. Thus, this develops the knowledge, skills, and abilities needed to implement sustainability.

Earlier research established that green innovation is shaped not only by technological solutions but also by organizational strategies, sustainability-oriented identities, and green creativity (García-Hernández et al., 2022). In the school context, these dimensions provide a foundation for understanding how green innovation can evolve into sustainable organizational practices and educational initiatives. Schools deliberately adopt strategies to achieve environmental goals, for example, reducing waste, conserving energy, recycling, or using sustainable resources. Sustainability may emerge as a part of what the school considers itself to be. In a school context, this could mean developing a school culture where teachers and pupils see the school as environmentally responsible. People within the organization develop new and creative ideas to solve environmental problems. For example, pupils designing products from recycled materials or creating innovative ways to reduce school waste.

Traditional innovation research primarily emphasized economic outcomes, including productivity, profitability, and short-term growth, with environmental considerations often treated as peripheral to the innovation process. The emergence of green innovation has progressively challenged this perspective by integrating environmental concerns into innovation strategies, organizational capabilities, and implementation processes. For a school, this could mean that an innovation is not considered successful merely because it is new or saves money. It should also contribute to resource conservation, waste reduction, environmental awareness, student participation, and sustainable school practices. Implementation involves how the innovation is introduced—for example, through school programmes, curriculum activities, co-curricular activities, recycling initiatives, energy-saving practices, green projects, or student-led innovation. Recent research further positions green innovation as a multidimensional process that generates environmental, social, and economic value while supporting long-term sustainability (Qin et al., 2025). This conceptual evolution provides an important basis for understanding how green innovation has progressively extended beyond technological solutions to encompass organizational practices, human capabilities, and sustainability-oriented processes, with significant implications for school sustainability. School sustainability should not be understood merely as the adoption of green technologies. It can also involve people, organizational practices, learning, creativity, participation, and long-term behavioral change.

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The conceptualization of green innovation has progressively expanded to encompass organisational capabilities, leadership, knowledge sharing, collaboration, and institutional support. Research has demonstrated that leadership and organisational capabilities can facilitate green innovation and creativity, while knowledge sharing may serve as an important mechanism linking leadership and innovation outcomes (Qiu et al., 2025; Shen et al., 2025; Vesterinen & Ratinen, 2023). In higher education, green innovation has similarly been associated with dynamic capabilities, knowledge exchange, university–industry collaboration, and institutional support, highlighting the role of educational institutions as important knowledge and innovation ecosystems (Qiu et al., 2025; Sposab & Rieckmann, 2024). Collectively, these findings indicate a shift from viewing green innovation primarily as a technological outcome towards understanding it as an organizational process enabled by leadership, capabilities, knowledge, collaboration, and institutional structures. However, this organizational perspective remains less developed in school settings, particularly regarding how such mechanisms support school-based green innovation and sustainability practices.

Within school settings, the emergence of green innovation can be traced to the broader development of the green school movement and the growing recognition of education as a mechanism for addressing environmental challenges. International milestones, particularly the 1972 Stockholm Conference and the 1992 Rio Earth Summit, strengthened the role of education in promoting environmental awareness and sustainability (García-Hernández et al., 2022). This development was subsequently reflected in initiatives such as nature-based education and Eco-Schools, which encouraged schools to integrate resource conservation, environmental management, and student participation into everyday practices (García-Hernández et al., 2022). By the early 2000s, the green school concept had further expanded to encompass environmentally responsible infrastructure, school-based sustainability practices, and learning environments that foster students' knowledge, attitudes, and connection with nature (García-Hernández et al., 2022). Practical approaches such as project-based learning, recycling, and school gardening further positioned schools as spaces for active sustainability engagement (García-Hernández et al., 2022). These developments provide an important historical foundation for understanding the subsequent emergence of green innovation in school sustainability. Nevertheless, research focusing specifically on green innovation and its implementation at the primary-school level remains comparatively limited, despite the importance of early education in developing sustainable knowledge, attitudes, and practices (García-Hernández et al., 2022).

The evolution of educational innovation has also introduced digital technologies as potential mechanisms for supporting sustainability-oriented learning. Information and communication technologies have been used in educational innovation through gamification, virtual simulations, and digital portfolios, providing opportunities for active experimentation while supporting more sustainable learning practices (García-Hernández et al., 2022). ICT in educational innovation processes related to sustainability is mostly associated with the design of gamification and experimentation strategies through virtual simulations, which can be motivating for students while facilitating the understanding of abstract concepts, especially for those with learning difficulties (García-Hernández et al., 2022). These strategies provide safe scenarios for active experimentation, achieving a higher degree of sustainability in educational proposals, while the use of e-portfolios can stimulate more sustainable behaviours and reduce paper consumption (García-Hernández et al., 2022).

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Social networks and fast communication channels are raising public awareness and creating global public opinion in favor of caring for the planet, a change influenced by educational innovation projects being developed in higher education across many countries (García-Hernández et al., 2022). More recent developments in Green Artificial Intelligence have extended this discussion by examining how intelligent technologies can improve learning efficiency, resource use, and educational management while contributing to broader sustainability objectives (Qiu et al., 2025). These direct effects generate positive spillover effects cascading into innovation performance, economic efficiency, and environmental sustainability, aligning with the United Nations Sustainable Development Goals (Qiu et al., 2025). Green AI technology affects learning efficiency, management and service efficiency, resource dependence, and costs through direct pathways, while student-oriented educational transformation and technological innovation serve as indirect pathways to support the transformation of educational systems (Qiu et al., 2025). However, the effectiveness of technological innovation is also influenced by organisational readiness, leadership support, available resources, and resistance to change(Shen et al., 2025). Sustainability competences in education have become a central concern across primary and secondary levels, with systems thinking competence and collaboration competence being the most commonly studied, followed by action-oriented and values thinking competence, leaving futures thinking competence less investigated.

Alongside technological developments, research has increasingly emphasised the competencies required for students and teachers to engage meaningfully with sustainability. Sustainability competence research across primary and secondary education has particularly examined systems thinking, collaboration, action-oriented thinking, and values thinking, while futures thinking remains comparatively less investigated (Vesterinen & Ratinen, 2023). Alongside technological developments, research has increasingly emphasised the competencies required for students and teachers to engage meaningfully with sustainability (Vesterinen & Ratinen, 2023). Sustainability competence research across primary and secondary education has particularly examined systems thinking, collaboration, action-oriented thinking, and values thinking, while futures thinking remains comparatively less investigated
More recent research similarly highlights critical thinking, systems thinking, and action competence as important foundations for preparing students to respond to complex sustainability challenges (Sposab & Rieckmann, 2024). A holistic approach to competence development is needed that integrates cognitive, affective, and behavioral components, though a research bias persists with a predominance of studies from Europe, particularly Germany and Sweden (Sposab & Rieckmann, 2024). Sustainable and green chemistry can be decisive in overcoming the insularity of chemical disciplines in high school, yet it is not well-embedded in educational practices (Celestino, 2023). This situation is slowly changing through the implementation of systems thinking in teaching practice, which shows interconnections between the molecular world and sustainability (Celestino, 2023).

The growing emphasis on sustainability competencies has also encouraged more interdisciplinary and systemic approaches to teaching. For example, sustainable and green chemistry has been proposed as a means of connecting disciplinary knowledge with broader sustainability challenges, with systems thinking helping students understand relationships between scientific concepts and environmental issues (Celestino, 2023). Such interdisciplinary approaches demonstrate a broader movement towards preparing students to understand and respond to complex sustainability challenges rather than treating environmental issues as isolated topics.(Celestino, 2023).

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At the same time, the sustainability of educational innovations has emerged as an important concern. Existing research identifies considerable variation in how the sustainability of educational innovations is conceptualised and notes the limited empirical foundation underlying some theoretical models(Prenger et al., 2022). A systematic review of 44 empirical publications identified four broad categories influencing the sustainability of educational innovations: school organisational characteristics, innovation characteristics, individual characteristics, and contextual characteristics(Prenger et al., 2022). Based on a systematic review of 44 empirical publications, the sustainability of educational innovations has been defined as the process of integrating the intervention's core aspects in organizational routines that are adaptive to ongoing work, with maintenance or continuation of improved results (Prenger et al., 2022). Four main factors influence the sustainability of educational innovations: school organizational characteristics, innovation characteristics, individual characteristics, and context characteristics (Prenger et al., 2022). There is no hierarchy to be found in the literature on these factors.

Articles on different innovations identify different factors of influence, and more research is needed on discriminating factors and how they interact within different forms of education (Prenger et al., 2022). The empirical-based model developed in this review should be validated in practice to create transparency and focus in sustainability research (Prenger et al., 2022). These findings suggest that sustaining educational innovation requires more than introducing a new intervention; it depends on the interaction between the innovation, individuals, organisational structures, and the wider educational context.

Taken together, the literature indicates that green innovation in educational contexts has evolved from relatively fragmented, technology-oriented approaches to broader approaches encompassing pedagogy, sustainability competencies, organisational capacity, leadership, collaboration, and systemic transformation. However, existing research remains fragmented across these dimensions, with limited understanding of how the focus of green innovation research in school sustainability has evolved. Gaps also remain in empirical validation, geographical representation, and the translation of green innovation principles into sustained educational practice across different educational contexts. Therefore, a historical examination of the literature is needed to clarify how the research focus has changed, which themes have emerged or gained prominence, and which areas remain underexplored. Accordingly, this study examines the historical development and thematic evolution of green innovation within school sustainability research from 2015 to 2026 based on Scopus-indexed publications.

Methodology

Data Collection

This historical review systematically traces the development of research on green innovation in school sustainability using publications indexed in the Scopus database. A predefined search strategy was used to identify relevant publications related to green innovation, school contexts, and sustainability. Retrieved records were screened using predetermined inclusion and exclusion criteria to ensure their relevance to the scope of the review. The selected publications were then organized chronologically to examine changes in publication trends, thematic emphasis, conceptual development, and emerging research directions from 2015 to 2026.

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Table 1: Search Strategy

Keyword	Green Innovation, School Sustainability
Inclusion	Environmental Science, Article, English, Education, Green Innovation, SDG 12
Exclusion	Other language, Other Subject Area, Other Document
Final Search String (Scopus)	Green Innovation School Sustainability Sustainability Development Goal 12 SDG 12 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SUBJAREA , "ENVI")) AND (LIMIT-TO (EXACTKEYWORD , "Education") OR LIMIT-TO (EXACTKEYWORD , "Green Innovation") OR LIMIT-TO (EXACTKEYWORD , "Sdg 12"))
Number of Primary Article	97

Source: Scopus

The search strategy combined three conceptual components: green innovation, school contexts, and sustainability or environmental terms. The publication-year limits restricted the search to studies published between 2015 and 2026, while the language filter limited the results to English-language publications**.**

The data collection strategy was designed to achieve high topical relevance, methodological consistency, and bibliographic quality in identifying literature on green innovation within school sustainability. The search was anchored on the core concepts of "Green Innovation" and "School Sustainability", with Sustainable Development Goal 12 (SDG 12) incorporated to strengthen alignment with responsible consumption and production. To ensure scholarly and disciplinary relevance, the inclusion criteria restricted the dataset to English-language journal articles at the final publication stage, indexed within environmental science, and associated with the exact keywords Education, Green Innovation, and/or SDG 12. These restrictions were theoretically justified because the review focuses specifically on the intersection between environmental sustainability, educational settings, innovation, and SDG 12 rather than on green innovation broadly. Articles published in other languages, document types, or subject areas were excluded to minimize conceptual heterogeneity and potential inconsistencies in interpretation. The use of Scopus as the sole data source further provides a consistent bibliographic environment in which publication metadata and indexing criteria can be systematically applied. Such a structured selection process enhances transparency and reproducibility while reducing the risk that the chronological patterns identified are driven by inconsistent retrieval or subjective source selection.

Application of these criteria resulted in a final dataset of 95 primary journal articles, which represents a focused evidence base for examining the evolution of green innovation research within school sustainability. The relatively targeted number of publications is not necessarily a limitation; rather, it indicates that the review deliberately prioritized specificity and conceptual coherence over volume. Broad searches of "green innovation" can generate thousands of records across business, engineering, manufacturing, technology, and environmental management, many of which have limited relevance to educational settings. By progressively restricting the dataset to education-related, environmentally oriented, peer-reviewed journal

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articles with explicit connections to green innovation and/or SDG 12, the present review improves the interpretability of longitudinal patterns. The 95 articles therefore provide a manageable yet sufficiently focused corpus for identifying changes in publication activity, research themes, conceptual orientations, and emerging directions. Importantly, the resulting trends should be interpreted as reflecting the Scopus-indexed scholarly literature that satisfies the predefined eligibility criteria, rather than the entire global body of research on school sustainability. This distinction strengthens the methodological defensibility of the review by clearly defining the boundaries within which its chronological findings can be generalized.

Data Clustering

In a chronological review of Green Innovation in School Sustainability, clustering publication data by temporal patterns provides an analytical framework for moving beyond a year-by-year description of publication output towards a more meaningful interpretation of how the research field has evolved. The literature was systematically retrieved from the Scopus database, using predefined keywords and advanced search strategies to identify relevant and high-quality publications. Following data collection, publications were grouped according to publication year and annual publication volume, enabling periods with similar research activity to be examined collectively. Such temporal clustering is important because individual annual fluctuations may not adequately represent the broader development of a research field; instead, grouping years with comparable publication patterns can reveal distinct stages of scholarly development, including periods of emergence, consolidation, transition, acceleration, or expansion. This approach therefore enhances the interpretability of longitudinal publication patterns by identifying meaningful shifts in research intensity and allowing changes across temporal phases to be discussed systematically. In particular, clustering helps distinguish relatively stable periods from substantial increases or decreases in scholarly attention, thereby providing a clearer basis for explaining the evolution of green innovation research within school sustainability. Importantly, the resulting clusters are interpreted as descriptive temporal phases derived from publication distribution, rather than as predetermined historical categories. This ensures that the classification remains grounded in the empirical evidence while providing a structured foundation for subsequent discussion of research trends, thematic developments, and emerging directions within the literature.

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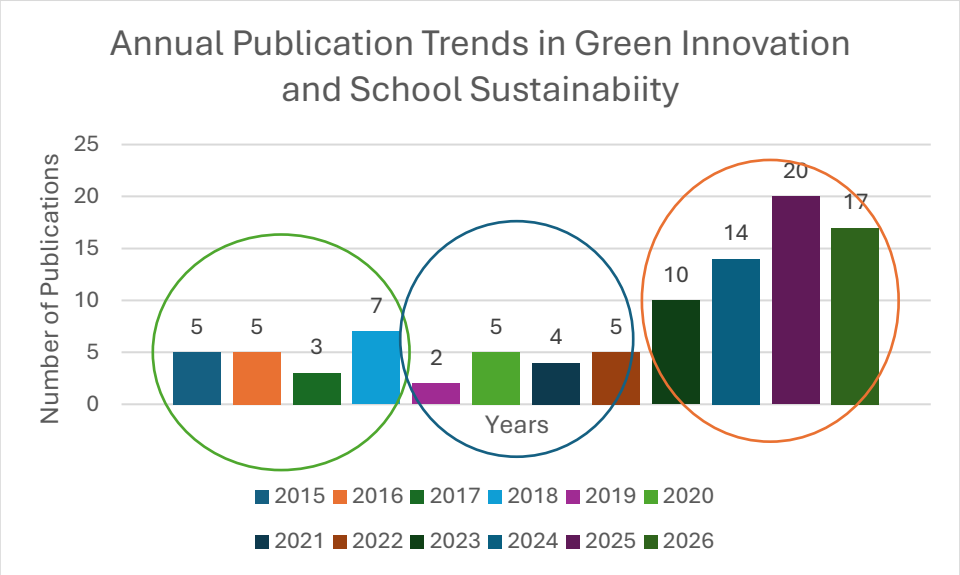


Figure 1: Annual Publication Trends in Green Innovation and School Sustainability (2015–2026)

Phase 1: Emergence and Foundation (2015–2018)

The period from 2015 to 2018 represents the Emergence and Foundation phase of research connecting green innovation, environmental sustainability, and educational environments. During this period, publication activity remained relatively modest, indicating that the topic was still developing as a distinct area of scholarly inquiry. The literature initially focused on environmental technologies, green infrastructure, behavioral factors, and educational applications before gradually broadening towards implementation, institutional support, and sustainability-oriented learning. This pattern suggests that early research primarily established the technological, behavioral, and conceptual foundations of green innovation in educational settings.

Phase 2: Consolidation and Transitional (2019–2022)

The Consolidation and Transitional Phase, covering 2019–2022, demonstrates a comparatively stable but modest level of scholarly production. Publication output fluctuated between three and five articles annually, with the lowest point occurring in 2019. Rather than representing sustained expansion, this pattern suggests a period of knowledge consolidation and gradual transition. Research during this phase appears to have maintained the established interest in environmental sustainability while progressively broadening attention towards innovation, educational transformation, and sustainability-oriented practices. The relatively limited publication volume indicates that green innovation in school sustainability had not yet become a strongly established research stream. Nevertheless, this phase is important because it represents the transition from initial conceptual exploration towards a more recognizable and structured research domain.

Phase 3: Acceleration and Expansion (2023–2026)

The period from 2023 onwards represents a pronounced Acceleration and Expansion Phase, characterized by a substantial increase in scholarly output. Publications rose from 11 articles

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in 2023 to 14 in 2024 and reached a peak of 21 articles in 2025. This sharp increase indicates growing scholarly attention towards the intersection of green innovation, education, and sustainability. The expansion may reflect the increasing prominence of sustainability-oriented education, climate action, technological innovation, and the implementation of the SDGs within educational institutions. The 2026 figure of 15 publications should, however, be interpreted cautiously if the Scopus data were collected before the completion of the publication year. Overall, the marked increase after 2022 suggests that green innovation in school sustainability has transitioned from a relatively niche research topic into an increasingly visible and expanding scholarly domain.

Result and Discussion

Annual Publication Trends in Green Innovation and School Sustainability (2015–2026)

Phase 1: Emergence and Foundation (2015–2018)

The first phase, covering 2015–2018, represents an emergence and foundation period in research connecting green innovation, environmental sustainability, and educational environments. In 2015, the literature remained relatively dispersed, with research addressing environmental innovation from behavioral, technological, architectural, and educational perspectives. Daskalakis (2016) demonstrated that behavioral factors could explain firms' environmental innovation decisions, with empirical modeling providing evidence that multiple behavioral elements influence innovation behavior. In the school context, (Varras et al., 2015) the development of extensive green roofs for four school sites in Piraeus, highlighting the potential of school infrastructure to provide environmental and social benefits through stormwater management, energy conservation, microclimate improvement, and biodiversity restoration. Lin (2015) demonstrated the practical potential of green building design through the Magic School of Green Technology, where appropriate and low-cost technologies produced substantial energy-saving outcomes. However, the 2015 evidence also contained broader environmental and non-school-specific studies, indicating that the research field had not yet developed a clearly defined school sustainability research boundary. This pattern suggests that early scholarship was primarily concerned with establishing the technical feasibility, environmental value, and behavioral foundations of green innovation rather than systematically examining school sustainability as an integrated educational phenomenon.

The 2016–2018 publications indicate a gradual broadening from individual technologies toward implementation, institutional support, educational engagement, and sustainable campus development. Haraksingh (2016) identified education and sensitization as important mechanisms for accelerating renewable-energy adoption, while Badi & Pryke (2016) that clear and manageable risk allocation could encourage sustainable-energy innovation within school-building projects, although excessive capital-cost risk could constrain implementation. Izvekova et al. (2016) green technologies and certification systems through examples of schools in the United States and Russia, reinforcing the relevance of green infrastructure to educational settings. By 2017, the literature showed stronger integration between sustainability and learning where Kawada (2017) stated that educational materials able to motivate elementary pupils to collect waste, while Rizzo et al. (2017) and Li et al. (2017) demonstrated how a university sustainability living laboratory could support co-designed green technologies using recycled materials. According to Li et al. (2017), extensive implementation is implemented in Taiwan's Sustainable Campus Program, linking environmental education,

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campus renovation, technological innovation, community engagement, and student learning. Denan et al. (2017) and Bonoli & Pulvirenti (2018), however, identified an implementation gap in Malaysia: environmental awareness was evident, but relatively few schools had progressed toward applying green technologies, indicating the importance of institutional, community, and physical-environmental support. The 2018 studies extended this trajectory toward green-school design, green technology, environmental applications, and behavioural dimensions. Denan et al. (2017) focused on climate-responsive design and green technology, while Bonoli & Pulvirenti (2018) focused on environmental applications of green roofs and façades. Collectively, Phase 1 shows a gradual shift from isolated technological and conceptual initiatives to more integrated approaches to school sustainability involving infrastructure, pedagogy, behaviour, and institutional implementation.

Phase 2 : Consolidation and Transitional (2019–2022)

The second phase, covering 2019–2022, demonstrates a noticeable expansion and integration of green innovation research, particularly through stronger connections between environmental innovation, education, behavioural practices, and institutional sustainability. Bahzar (2019) examined green transformational leadership, ethical leadership, green creativity, and eco-innovation within higher educational institutions, with PLS-SEM results indicating that leadership and eco-innovation contributed positively to environmental performance and energy efficiency. This finding suggests an increasing recognition that green innovation is influenced not only by technological solutions but also by organisational leadership and institutional capacity. More directly related to school sustainability, Kamis et al. (2019)investigated Green Skills among Year Five primary school pupils through a quasi-experimental intervention. The findings showed that pupils demonstrated good levels of waste management, 3R, and water-use practices, with no significant gender differences. The study consequently demonstrated the potential for structured Green Skills education to translate sustainability concepts into practical environmental behaviour. Together, the 2019 findings indicate an important shift from the predominantly infrastructure-oriented concerns observed in the earlier phase toward human capability, leadership, educational intervention, and practical sustainability behaviour.

During 2020–2021, the literature became increasingly concerned with the adoption, diffusion, implementation, and institutionalisation of environmental innovation. Madueke & Mkpado (2020) found that financial constraints, limited skills, and low-quality products restricted the adoption of environmentally friendly infrastructure, highlighting that awareness alone may not guarantee implementation. Similarly, Listiana et al. (2020) reported low adoption of environmentally friendly agricultural innovations, with innovation skills, extension support, cosmopolitanism, and access to information technology influencing adoption. In educational settings, Saukkonen et al. (2020) demonstrated the potential of intensive short-term interventions to influence sustainability understanding and motivation, while Otieno et al. (2020)documented the expansion of Kenya's Eco-schools programme from a small pilot to more than 1,000 schools. The programme increasingly incorporated experiential learning, green enterprise development, renewable energy, water management, green innovation, energy efficiency, and integrated waste management, although funding, teacher turnover, and whole-institution implementation remained challenges. In 2021, Sergienko et al. reported that environmentally innovative construction technologies could reduce the carbon footprint of school-related buildings, while Utomo & Ling (2021) illustrated how industry-linked project learning could expose students to green technology through practical innovation projects. These findings collectively indicate a transition towards implementation-oriented

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sustainability, where technological innovation becomes increasingly connected with learning, institutional practice, resource efficiency, and real-world problem solving.

By 2022, the research landscape further broadened towards systemic sustainability, digital transformation, circular economy, food systems, and measurable environmental performance. Mohamed Hashim et al. (2022) proposed a conceptual model for sustainable digital transformation in universities, emphasising the integration of technology, sustainability, leadership, and organisational implementation. Ospanova et al.(2022)similarly advanced a conceptual understanding of the green economy as a pathway towards sustainable development. Pacifico et al. (2022) provided a practical example connecting green technology with school-age nutrition and responsible consumption through solar drying technology, demonstrating how technological innovation could simultaneously address food loss, nutrition, and SDG-related concerns. Cañete & Alvarez (2022) showed that green technologies such as composting and recycling could contribute to improved agricultural productivity, although demographic and experience-related factors influenced adoption efficiency. Stoian et al. (2022) further established positive relationships between eco-innovation, energy productivity, renewable-energy consumption, and environmental performance at the European level. Overall, Phase 2 reflects a clear maturation of the research landscape, moving beyond isolated green technologies towards more integrated socio-technical approaches. Across 2019–2022, green innovation became increasingly connected with human capability, leadership, educational intervention, institutional implementation, resource efficiency, circular practices, and measurable environmental performance. This transition suggests that sustainability was progressively conceptualised not merely as the adoption of environmental technologies, but as an interconnected process involving people, pedagogy, institutions, and technological systems.

Phase 3: Acceleration and Expansion (2023–2026)

The third phase, covering 2023–2026, represents a period of accelerated and increasingly diversified research on green innovation within educational and related institutional contexts. Compared with the earlier phases, research during this period demonstrates a broader conceptualisation of green innovation, extending beyond individual technologies and environmental practices towards competencies, curriculum integration, institutional leadership, digital transformation, partnerships, and system-level sustainability.

In 2023, research increasingly positioned education as an important mechanism for developing competencies required for the green transition. Studies on green skills emphasised the integration of competencies such as reuse, recycling, reduction, repair, reassembly, and energy conservation into educational programmes. Other studies demonstrated how academic design projects could translate environmental innovation into practical applications through material reduction, computational design, and the use of reclaimed materials. These developments indicate that green innovation was increasingly being conceptualised not merely as a technological outcome but also as a learning process through which students develop knowledge, skills, creativity, and problem-solving capabilities.

In 2024, the research focus expanded further from individual competencies and technological applications towards institutional systems, partnerships, leadership, and sustainable educational environments. Suwanprapha et al. (2024)highlighted the potential of environmental schools to integrate interdisciplinary learning, digital technologies, green innovation, and SDG-oriented education, while also identifying curriculum design, resource

management, theory–practice integration, and cross-sector collaboration as continuing challenges. Jing (2024) demonstrated the importance of school–enterprise cooperation in strengthening green innovation, while Rudyshyn et al. (2024) highlighted the role of environmental leadership in developing students' motivation, environmental culture, and leadership qualities. Similarly, research on green laboratory implementation emphasised energy and water conservation, waste reduction, recycling, and the use of green technologies. Collectively, these studies suggest a movement towards the institutionalisation of sustainability, in which green innovation becomes embedded within educational environments, leadership practices, partnerships, and resource management.

The increase to 21 publications in 2025 represents the most productive point within Phase 3 and signals a substantial diversification of research directions. Research increasingly addressed teachers, students, curriculum, digital learning, green technology, environmental knowledge, and green leadership. Balouch et al. (2025) examined relationships between green transformational leadership, green innovation performance, and environmental behaviours among elementary school teachers, while Listopadzka et al., 2025 highlighted the influence of curriculum flexibility, teacher roles, competency development, and institutional context on preparation for a digital green economy. Qi (2025)further demonstrated the role of education in strengthening environmental awareness and behavioural norms, although limitations related to instructional resources, cost, and local support continued to constrain implementation. These findings indicate that the field was increasingly concerned not only with what green innovation is, but also with how it can be developed, implemented, and sustained through educational systems.

By 2026, publication output declined to 15 studies, but the thematic direction became more explicitly systemic and transformative. Research connected green innovation with national innovation environments, education systems, R&D capacity, environmental performance, traditional knowledge, STEAM education, and institutional sustainability. Cavalheiro et al. highlighted relationships among innovation environments, education-related indicators, economic development, and environmental performance, while Kano et al. (2026) presented examples involving student innovation and culturally responsive STEAM education. Other studies further emphasised workplace green education, environmental training, knowledge sharing, and policy support. Taken together, these developments suggest that green innovation research has increasingly moved towards a system-level perspective, involving the interaction of curriculum, teachers, learners, technology, infrastructure, partnerships, policy, and organisational learning.

Conclusions

This chronological review examined the evolution of research on green innovation and school sustainability from 2015 to 2026, based on publications indexed in the Scopus database. The review aimed to trace the development of research trends, identify major changes in research focus, and examine how green innovation has progressively been conceptualised and implemented within educational and school sustainability contexts.

The chronological analysis identified three developmental phases. The Emergence and Foundation Phase (2015–2018) was characterised mainly by environmental technologies, green infrastructure, environmental awareness, behavioural factors, and early applications of green innovation in educational settings. The Consolidation and Transition Phase (2019–2022)

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demonstrated a broader emphasis on green skills, experiential learning, environmental behaviour, leadership, institutional implementation, resource efficiency, and circular practices. The Acceleration and Expansion Phase (2023–2026) showed increasing diversification of research towards sustainability competencies, curriculum integration, digital technologies, environmental leadership, partnerships, teacher and student development, and system-level sustainability. Overall, the publication trend indicates increasing research activity, with the highest annual output occurring in 2025, followed by a decline in 2026.

Across the three phases, the research domain demonstrates a clear transformation from viewing green innovation primarily as environmental technology and infrastructure towards understanding it as an integrated educational, organisational, and socio-technical process. Methodological and conceptual development also became broader, with increasing attention to practical implementation, human capabilities, institutional support, collaboration, digital transformation, and sustainability-oriented learning. The recent literature further demonstrates the increasing integration of technology, competencies, leadership, curriculum, and organisational systems in addressing sustainability challenges within educational contexts.

The chronological organisation of the literature contributes to a deeper understanding of the field by showing how these changes occurred over time. Rather than examining research themes as separate and static categories, the chronological approach reveals the progression and transformation of research priorities across different periods. It therefore provides a structured perspective on the emergence of new research directions, the expansion of established areas, and the increasing integration of previously separate dimensions of green innovation and school sustainability.

The findings have practical implications for educational institutions, curriculum development, teacher preparation, and sustainability-oriented school programmes. The observed progression suggests that effective green innovation requires more than the adoption of environmental technologies. It requires the integration of sustainability knowledge and competencies into learning, supportive leadership, institutional capacity, collaboration, appropriate technologies, and opportunities for practical engagement. For future research, greater attention should be given to how green innovation can be translated into sustained practices within real school environments and how such practices can contribute to measurable sustainability outcomes, particularly in relation to responsible consumption and production.

Several limitations should also be acknowledged. The review relied on Scopus as the primary database, and therefore relevant publications indexed in other databases may not have been captured. The search was also restricted by the selected keywords, English-language publications, and the 2015–2026 timeframe, which may have influenced the range of studies identified. In addition, the rapidly developing nature of research published in 2026 means that the representation of the most recent period may continue to change as further publications are indexed. Future reviews could therefore expand the database coverage, incorporate broader search terms, and examine interdisciplinary evidence from education, environmental science, technology, organisational studies, and sustainability research. Further empirical research conducted in real school settings is also needed to strengthen understanding of the implementation and long-term sustainability of green innovation practices.

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Overall, this chronological review demonstrates that green innovation in school sustainability has developed from a relatively technology-oriented research area into a broader and increasingly integrated field involving pedagogy, competencies, leadership, technology, institutional capacity, collaboration, and systemic sustainability. A time-based perspective is therefore valuable for capturing the dynamic development of scientific knowledge, identifying emerging directions, and understanding how research priorities transform over time. Such chronological evidence can support future innovation, strengthen evidence-based educational development, and guide more sustainable approaches to school practice and responsible consumption and production.

Acknowledgements:	The authors would like to express their sincere gratitude to Universiti Sains Malaysia for providing the necessary resources and support throughout the course of this research. Special appreciation is extended to colleagues and peers who contributed valuable insights and constructive feedback, which greatly enhanced the quality of this paper.
Funding Statement:	"No Funding"
Conflict of Interest Statement:	The authors declare that there is no conflict of interest regarding the publication of this paper. All authors have contributed to this work and approved the final version of the manuscript for submission to the International Journal of Modern Education (IJMOE).
Ethics Statement:	This study did not involve any human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the research was conducted in accordance with accepted academic integrity and ethical publishing standards.
Author Contribution Statement:	All authors contributed significantly to the development of this manuscript. Norazrina Osman contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission. Ahmad Zamri Khairani was responsible for the conceptualization, methodology, and overall supervision of the study. Wan Azani Mustafa handled data collection, analysis, and interpretation of results.

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Volume: 8 Issue: 32 (December 2026) PP. 86-104

References

Badi, S. M., & Pryke, S. (2016). Assessing the impact of risk allocation on sustainable energy innovation (SEI): The case of private finance initiative (PFI) school projects. International Journal of Managing Projects in Business, 9(2), 259–281. https://doi.org/10.1108/IJMPB-10-2015-0103

Bahzar, M. (2019). Effects of green transformational and ethical leadership on green creativity, eco-innovation and energy efficiency in higher education sector of Indonesia. International Journal of Energy Economics and Policy, 9(6), 408–414. https://doi.org/10.32479/ijeep.8372

Balouch, S., Vakili Yekan, T., & Kordi Tamandani, S. (2025). Environmental knowledge nexus: Catalysts for green innovation. Human Behavior and Emerging Technologies, 2025(1), 7270589. https://doi.org/10.1155/hbe2/7270589

Bonoli, A., & Pulvirenti, B. (2018). Urban green technologies for energy saving: Numerical simulation of heat transfer between green façades and green roofs and the local outdoor environment. In F. Orsini, G. P. Gianquinto, G. Pennisi, L. Cremonini, & T. Georgiadis (Eds.), Acta Horticulturae (pp. 11–19). International Society for Horticultural Science. https://doi.org/10.17660/ActaHortic.2018.1215.2

Cañete, D. C., & Alvarez, M. T. S. (2022). The efficiency of technical and economic utilization of Cagayan Valley green dairy technologies. Universal Journal of Agricultural Research, 10(2), 108–117. https://doi.org/10.13189/ujar.2022.100202

Celestino, T. (2023). High school sustainable and green chemistry: Historical–epistemological and pedagogical considerations. Sustainable Chemistry, 4(3), 22. https://doi.org/10.3390/suschem4030022

Cillo, V., Petruzzelli, A. M., Ardito, L., & Giudice, M. Del. (2019). Understanding sustainable innovation: A systematic literature review. Corporate Social Responsibility and Environmental Management. https://doi.org/10.1002/csr.1783

Denan, Z., Awang, A. H., Mazlan, M. A. H., Majid, N. H. A., Rahim, Z. A., & Sanusi, N. A. Z. (2017). The implementation of environmental education and green programs in schools to achieve sustainability. Advanced Science Letters, 23(7), 6261–6265. https://doi.org/10.1166/asl.2017.9248

García-Hernández, A., García-Villanueva Muñoz-Repiso, A., Casillas-Martín, S., & Cabezas-González, M. (2022). Sustainability in digital education: A systematic review of innovative proposals. Education Sciences, 13(1), 33. https://doi.org/10.3390/educsci13010033

Guinot, J., Barghouti, Z., & Chiva, R. (2022). Understanding green innovation: A conceptual framework. Sustainability, 14(10), 5787. https://doi.org/10.3390/su14105787

Haraksingh, I. (2016). Renewable energy against an oil and gas background: Challenges, drivers, and case studies. In Renewable Energy in the Service of Mankind Vol. II (pp. 311–323). Springer International Publishing. https://doi.org/10.1007/978-3-319-18215-5_28

Izvekova, O., Roy, V., & Murgul, V. (2016). “Green” technologies in the construction of social facilities. Procedia Engineering, 165, 1806–1811. https://doi.org/10.1016/j.proeng.2016.11.926

Jing, L. C. (2024). How does university-industry collaboration drives the green innovation? SAGE Open, 14(3). https://doi.org/10.1177/21582440241274500

Kamis, A., Kob, C. G. C., Affand, H. M., & Yunus, F. A. N. (2019). The effect of implementing the green skills module on design technology subject: Assessing the pupils’ green skills

practices. Journal of Engineering Science and Technology, 14(Special Issue on ICEES2018), 18–25.

Kano, K., Santos, D., & Raman, S. (2026). Traditional knowledge for green innovation with Japanese persimmon tannin, Kakishibu. Springer Nature. https://doi.org/10.1007/978-981-95-7805-4

Kawada, K. (2017). Development of educational material to support motivation of picking up rubbish for elementary school students. IEEJ Transactions on Electronics, Information and Systems, 137, 76–81. https://doi.org/10.1541/ieejeiss.137.76

Li, Y.-Y., Chen, H.-H., Shao, W.-C., Jing, S.-R., Chiu, F.-Y., & Su, H.-J. J. (2017). Practices of innovative technology and education for sustainability in Taiwan sustainable campus program. In C. S. S.-J., L. F.-T., W. D.-W., & C. L.-J. (Eds.), Proceedings of the 2017 Pacific Neighborhood Consortium Annual Conference and Joint Meetings: Data Informed Society (pp. 15–22). Institute of Electrical and Electronics Engineers. https://doi.org/10.23919/PNC.2017.8203517

Lin, H.-T. (2015). The first zero-carbon architecture in Taiwan: The Magic School of Green Technology, NCKU. In Refrigeration Science and Technology (pp. 116–126). International Institute of Refrigeration. https://doi.org/10.18462/IIR.ICR.2015.1012

Listiana, I., Hudoyo, A., Prayitno, R. T., Mutolib, A., Yanfika, H., & Rahmat, A. (2020). Adoption level of environmentally friendly paddy cultivated innovation in Pringsewu District, Lampung Province, Indonesia. Journal of Physics: Conference Series, 1467(1), 012025. https://doi.org/10.1088/1742-6596/1467/1/012025

Listopadzka, E., Dunajko, I. K., & Prokopowicz, D. (2025). Teachers as architects of green readiness: Future-ready competencies in education. Procedia Computer Science, 928–936. https://doi.org/10.1016/j.procs.2025.09.213

Madueke, C. I., & Mkpado, M. (2020). Prospects for and constraints to investment in environmentally friendly infrastructure in Western Nigeria (pp. 91–117). https://doi.org/10.1007/978-3-030-44180-7_5

Maier, D., Maier, A., Aşchilean, I., Anastasiu, L., & Gavriş, O. (2020). The relationship between innovation and sustainability: A bibliometric review of the literature. Sustainability, 12(10), 4083. https://doi.org/10.3390/su12104083

Mohamed Hashim, M. A., Tlemsani, I., & Matthews, R. D. (2022). A sustainable university: Digital transformation and beyond. Education and Information Technologies, 27, 8961–8996. https://doi.org/10.1007/s10639-022-10968-y

Oduro, S., Maccario, G., & De Nisco, A. (2021). Green innovation: A multidomain systematic review. European Journal of Innovation Management. https://doi.org/10.1108/EJIM-10-2020-0425

Ospanova, A., Popovychenko, I., & Chuprina, E. (2022). Green economy – Vector of sustainable development. Problemy Ekorozwoju, 17(1), 171–181. https://doi.org/10.35784/pe.2022.1.16

Otieno, D., Wandabi, D., & Dixon, L. (2020). Eco-Schools Kenya: Practising education for green economy and sustainability (pp. 245–267). https://doi.org/10.1007/978-3-030-46820-0_14

Pacifico, I., De Gara, L., Stellari, A., Marinoni, L., & Cattaneo, T. M. P. (2022). The application of solar drying process for the valorisation of papaya fruit. European Food Research and Technology, 248(3), 857–867. https://doi.org/10.1007/s00217-021-03932-6

Prenger, R., Tappel, A., Poortman, C., & Schildkamp, K. (2022). How can educational innovations become sustainable? A review of the empirical literature. Frontiers in Education, 7, 970715. https://doi.org/10.3389/feduc.2022.970715

Qi, C. (2025). The role of educational science in environmental management and green technology adoption in rural revitalization through interview-based insights. Scientific Reports, 15(1). https://doi.org/10.1038/s41598-025-95791-4

Qin, X., Muskat, B., Ambrosini, V., Mair, J., & Chih, Y.-Y. (2025). Green innovation implementation: A systematic review and research directions. Journal of Management, 52, 255–282. https://doi.org/10.1177/01492063241312656

Qiu, Y., Lu, Y., Xia, G., Munir, M., Khan, H., & Dewi, D. A. (2025). Leveraging green AI technology to build sustainable schools: A conceptual model based on AI agents. Journal of Electronic Research and Application, 9(2). https://doi.org/10.26689/jera.v9i2.9957

Rudyshyn, S., Truskavetska, I., Romanyuk, S., Vakal, A., & Hnatyuk, V. (2024). The role of motivation factors in education for the development of student's environmental leadership in HEIs. Journal of Education and Learning, 18(1), 1–8. https://doi.org/10.11591/edulearn.v18i1.21016

Saukkonen, J., Tarasanski, P., & Hämäläinen, T. (2020). Impacting mindset and innovation on sustainability via global thematic hackathon. In D. N. A. (Ed.), Proceedings of the European Conference on Innovation and Entrepreneurship, ECIE (pp. 595–603). Academic Conferences and Publishing International Limited. https://doi.org/10.34190/EIE.20.047

Sergienko, O. I., Dmitrieva, A. P., Agakhanants, P. F., Tereshchenko, O. V., Yulmetova, R. F., & Ulyanov, N. B. (2021). Environmental innovations in the construction of social infrastructure facilities in agricultural holdings. IOP Conference Series: Earth and Environmental Science, 852(1), 012093. https://doi.org/10.1088/1755-1315/852/1/012093

Shen, Y., Deng, Y., Xiao, Z., Zhang, Z., & Dai, R. (2025). Driving green digital innovation in higher education: The influence of leadership and dynamic capabilities on cultivating a green digital mindset and knowledge sharing for sustainable practices. BMC Psychology, 13. https://doi.org/10.1186/s40359-025-02552-z

Sposab, K., & Rieckmann, M. (2024). Development of sustainability competencies in secondary school education: A scoping literature review. Sustainability, 16(23), 10228. https://doi.org/10.3390/su162310228

Stoian, M., Brad, L., & Zaharia, A. (2022). Drivers of the European Union's environmental performance. Frontiers in Environmental Science, 10, 954612. https://doi.org/10.3389/fenvs.2022.954612

Suwanprapha, M., Pholpuntin, S., Chaleysub, S., & Jitsupa, J. (2024). Transformation for environmental schools: Opportunities and challenges. Journal of Food Health and Bioenvironmental Science, 17(3), 64–73.

Takalo, S. K., Tooranloo, H., & Parizi, Z. S. (2021). Green innovation: A systematic literature review. Journal of Cleaner Production, 311, 122474. https://doi.org/10.1016/j.jclepro.2020.122474

Utomo, H. D., & Ling, S.-N. G. (2021). CDIO approach in developing solution minded learners. In J. Bennedsen, K. Edstrom, M. S. Gudjonsdottir, I. Saemundsdottir, N. Kuptasthien, J. Roslof, & A. Sripakagorn (Eds.), Proceedings of the International CDIO Conference (pp. 214–223). Chalmers University of Technology.

Varras, G., Vozikis, K.-Th., Myriounis, C., Tsirogiannis, I. L., & Kitta, E. (2015). Design of extensive green roofs for the major school plants of Piraeus. In J. C. Mauget & S. Godet (Eds.), Acta Horticulturae (pp. 959–966). International Society for Horticultural Science. https://doi.org/10.17660/ActaHortic.2015.1099.122

International Journal of Modern Education
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Volume: 8 Issue: 32 (December 2026) PP. 86-104

Vesterinen, M., & Ratinen, I. (2023). Sustainability competences in primary school education: A systematic literature review. Environmental Education Research, 30, 56–67. https://doi.org/10.1080/13504622.2023.2170984