

Mapping the Intersection of Education, Green Economy, and Green Jobs: A Bibliometric Analysis

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ABSTRACT

This study aims to explore the relationship between Education for Sustainable Development (ESD) and green jobs by mapping the scientific landscape of publications in the field. A bibliometric design was employed using Scopus data covering the period 2000–2025. The dataset consisted of journal articles and conference proceedings, analyzed with the Bibliometrix R-package to examine publication trends, citation performance, collaboration networks, keyword co-occurrence, and thematic evolution. The results indicate a steady rise in publications since 2010, with rapid growth after 2019 and a peak in 2024. Sustainable development and green economy emerged as core themes, while engineering education, green jobs, and curricula appeared as emerging areas of interest. The analysis also shows that the field is dominated by advanced economies such as China, the United States, and Finland, while Indonesia and other developing countries are beginning to play a more visible role. These findings imply that stronger integration of ESD into higher education and vocational pathways, supported by cross-country collaboration and curriculum innovation, is essential to prepare a workforce for inclusive and sustainable green transitions.

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Introduction

The global shift toward a low carbon economy is transforming labor markets and skill formation and it places education at the center of sustainable development agendas (Bilqis et al., 2024; Budiarto et al., 2024). Green jobs are increasingly framed as vehicles for climate mitigation and inclusive growth, with direct implications for how societies cultivate work-ready sustainability competences (Prasetyani et al., 2021; Pratomo et al., 2024). Education for Sustainable Development offers a unifying lens to align curricula, assessment, and partnerships with the capabilities demanded by green transitions. In emerging economies, large youth cohorts and rapid industrial restructuring create both risks and opportunities for workforce participation. Clarifying how the scholarly field connects education pathways with green employment outcomes is therefore essential for evidence informed policy and institutional planning.

Technical and vocational education has been positioned as a principal conduit for embedding green skills and preparing graduates for greening occupations (Handayani et al., 2020; SetiAwan, 2017). Recent assessments reveal gaps between curricular intentions and the maturity of competencies among teachers and students, indicating the need for strengthened pedagogy, assessment, and school culture (Fitriyanto & Triyono, 2023; Mutohhari et al., 2025). Programmatic proposals emphasize 6R work cultures and immersive learning technologies as scaffolds for competence formation. Employer demand for waste management, communication, and innovation skills often outpaces provision in vocational pathways. These trends suggest TVET aligned with ESD remains a critical yet consolidating pillar of the green transition.

Within higher education, studies link ecopreneurial orientations and self-efficacy to curricular support and technology mediated learning that can catalyze sustainability competencies (Alfarizi & Herdiansyah, 2024; Damayanti et al., 2025). Scholarship in faith based contexts highlights the role of normative frames and value centered pedagogy in shaping pro environmental attitudes and actionable skills (Fauziah et al., 2024; Ismail et al., 2025). This evidence underscores that green competence is simultaneously technical, socio cultural, and ethical. Emphasis on higher order thinking aligns with the complex problem solving required by sustainability transformations. Consequently, multi dimensional curriculum design that integrates content knowledge, ethical reasoning, and digital or green technologies has gained prominence.

Beyond formal curricula, policy instruments and community programs create enabling environments for green behaviors and learning opportunities (Herdiansyah et al., 2019; Rosilawati & Rahmawati, 2023). Waste bank governance and corporate social responsibility initiatives provide platforms for environmental education, transparency, and local capacity building (Muljaningsih et al., 2023; Rahardja et al., 2024). Such mechanisms can function as lived ESD ecosystems that reinforce classroom learning. They

illustrate the importance of multi stakeholder collaboration and accountability to sustain behavioral change. Nevertheless, their scalability and alignment with labor market pathways remain uneven across regions and sectors.

Community based initiatives further integrate livelihoods, conservation, and informal learning through ecotourism and place based education (Manaf et al., 2025; Muhammad et al., 2023). Climate village programs and digital platforms demonstrate how adaptation and mitigation efforts can be coupled with public education and social enterprise to support green economies (Awatara et al., 2025; Ririhena et al., 2024). These cases point to the centrality of local governance, participation, and socio technical infrastructures in enabling green capabilities. They situate ESD within concrete territorial challenges, from watershed pollution to climate related hazards. As such, they provide fertile contexts for examining how learning processes articulate with green employment opportunities.

Despite this progress, the literature documents tensions between market centric framings of conservation education and structural drivers of unsustainability that impede transformative outcomes (Acciaoli & Afiff, 2018; Hamid & Lubis, 2024). Ambiguities in defining green jobs, risks of greenwashing, and uneven governance capacities complicate evidence on how education translates into quality employment and just transitions (Hastuti & Purnama, 2024; Subyantoro et al., 2022). Many studies remain single case, methodologically fragmented, or highly context specific, which limits cumulative learning. There is also a geographic skew toward developed economies, with emerging regions underrepresented in comparative syntheses. A systematic field level overview is therefore needed to clarify thematic evolution, actor networks, and knowledge gaps at the nexus of education and green jobs.

This study addresses these needs by conducting a bibliometric and science mapping analysis of publications that link Education for Sustainable Development and green jobs for the period 2000 to 2025 using Bibliometrix. By integrating performance indicators, co authorship and co citation networks, and thematic evolution analysis, the study situates educational approaches, governance mechanisms, and industrial strategies within broader sustainability transitions (Maharani, 2025; Sholehah et al., 2024). The analysis contributes empirical baselines for curriculum and policy design in sectors such as renewable energy and circular economy where education employment linkages are intensifying (Adriana & Setiawan, 2021; Ilmi, 2021). It also foregrounds emerging contexts and actor constellations to guide comparative research agendas and targeted capacity building. Overall, the article advances conceptual and practical understanding of how education systems can catalyze green employment pathways while supporting inclusive and regionally responsive transitions.

Methods

This study employed a bibliometric research design to examine the evolution of scholarship at the intersection of Education for Sustainable Development (ESD) and green jobs. Bibliometric methods were selected for their capacity to quantify large publication sets, surface emerging trends, and map intellectual structures in a field (Irawan et al., 2024). The approach combined descriptive performance analysis and science-mapping techniques to capture the topic's multidisciplinary nature and its development across contexts and time.

Bibliographic records were retrieved from Scopus because of its broad coverage of peer-reviewed journals and international conference proceedings. The search string comprised two clusters of terms. The first targeted green employment concepts: "green jobs," "green employment," "green economy," and "sustainable jobs." The second targeted educational dimensions: "education for sustainable development," "sustainability education," "education," "higher education," "environmental education," "renewable energy training," "green skills," "workforce transition," "vocational education," and "skills development." The time window covered 2000 to 2025. Only documents classified as articles or conference papers were included for quality and comparability. The search was executed in August 2025 and exported in BibTeX format for analysis.

Preprocessing included removal of duplicates, normalization of author names, and harmonization of keywords to improve analytical consistency. A metadata quality audit was run prior to analysis. Core fields used throughout the study were complete or near complete, including authors, document type, language, publication year, title, and total citations. Several fields exhibited non-trivial missingness, for example Keywords Plus and DOI, and two fields were unavailable in the export, namely cited references and science categories. Analyses that depend on those unavailable fields were not performed or were substituted with indicators supported by the dataset. This ensured that results relied on variables with sufficient completeness.

Descriptive performance indicators profiled annual scientific production, document types, and source outlets, as well as productivity by countries, institutions, and authors. Citation analyses identified the most globally cited documents and summarized country-level citation performance. Collaboration analysis examined co-authorship structures at author, institution, and country levels, and reported single-country versus multiple-country publications to indicate the degree of international collaboration. Conceptual structures were investigated using keyword co-occurrence networks and thematic mapping to locate motor, basic, emerging, and declining themes. Thematic evolution was assessed across three periods that reflect the dataset's temporal distribution: 2001–2008, 2009–2016, and 2017–2025. All analyses were conducted with

the Bibliometrix R package, which provides routines for performance analysis, network construction, and visualization (Irawan et al., 2024).

Result and Discussion

1. Trends in Scientific Production

The Scopus dataset used in this analysis consists of 564 articles and demonstrates strong metadata quality for core variables. The fields Author, Document Type, Language, Publication Year, Title, and Total Citation were fully available without missing values, indicating high suitability for analyzing publication trends and citation performance. As shown in Table 1, several variables exhibited tolerable levels of incompleteness, namely Abstract with 0.53% missing, Affiliation 1.42%, Corresponding Author 1.42%, Keywords 4.08%, Journal 4.79%, and DOI 9.75%. Two components, however, require greater attention: Keywords Plus, which was missing 35.82%, and both Cited References and Science Categories, which were entirely absent (100%). These gaps imply that thematic mapping and subject classification must be interpreted with caution, although the reliability of scientific production and citation analyses remains robust due to the completeness of key variables.

Table 1. Missing Data Table

Metadata	Description	Missing Counts	Missing %	Status
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
AB	Abstract	3	0.53	Good
C1	Affiliation	8	1.42	Good
RP	Corresponding Author	8	1.42	Good
DE	Keywords	23	4.08	Good
SO	Journal	27	4.79	Good
DI	DOI	55	9.75	Good
ID	Keywords Plus	202	35.82	Poor
CR	Cited References	564	100.00	Completely missing
WC	Science Categories	564	100.00	Completely missing

Based on the annual scientific production graph from 2000 to 2025, the development of publications shows a gradual pattern with a very low phase until around 2010, followed by a slow increase after 2011. A sharp acceleration occurred after 2019,

reaching its peak in 2024 with more than 130 documents, before slightly declining in 2025 (the data were collected in August 2025, so the number may still increase). As illustrated in Figure 1, this pattern indicates that the topic linking education for sustainable development and green jobs has entered the global research mainstream after a long incubation period.

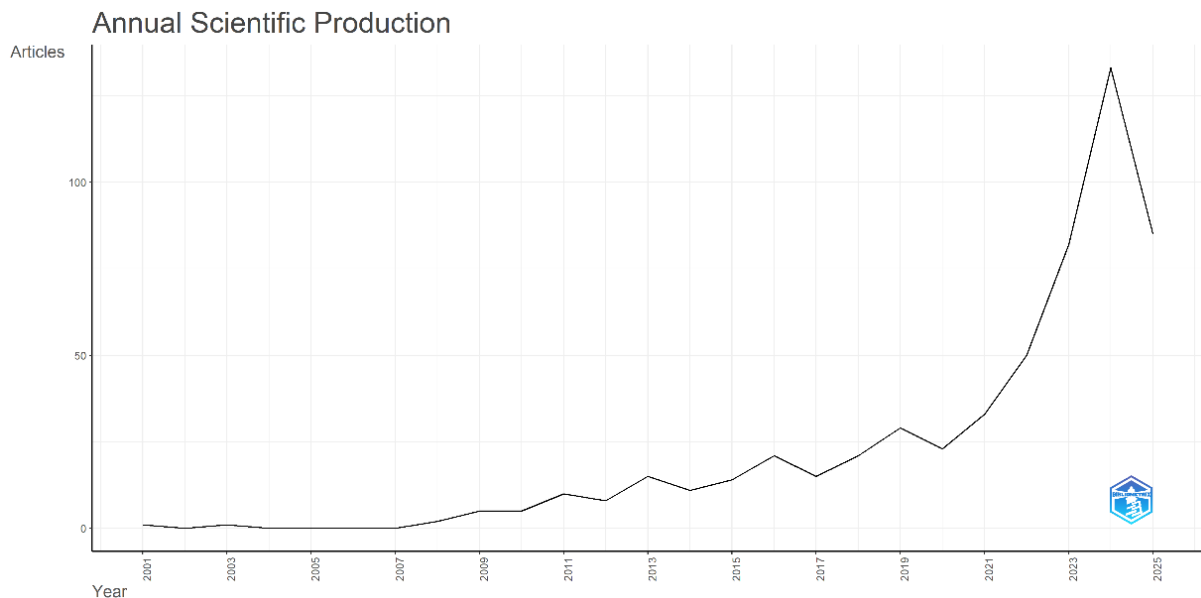


Figure 1. Annual Scientific Production

The sharp increase since 2019 aligns with the strengthening of the green transition agenda and the growing demand for sustainability skills in the labor market. The literature summarized in the introduction also positions education as the core driver for developing sustainability-oriented work competencies, in line with climate policy initiatives and the SDGs, which has led to rising academic interest and a surge in publication output (Bilqis et al., 2024; Budiarto et al., 2024; Prasetyani et al., 2021; Pratomo et al., 2024). Thus, this quantitative trend is not merely a bibliometric phenomenon but a reflection of the dynamic interplay between industrial needs, public policy, and curricular innovation in higher and vocational education.

2. Sources and Citation Performance

The analysis of publication sources shows that research on the linkage between sustainability education and green jobs is distributed across various international journals and conference proceedings, with a particularly strong dominance of Sustainability (Switzerland). This journal is recorded as the most productive outlet with 56 documents, far surpassing Resources Policy (22 documents), Environmental Science and Pollution Research (19 documents), and Lecture Notes in Networks and Systems (15 documents). As illustrated in Figure 2, this distribution indicates that, in addition to broad multidisciplinary journals such as Sustainability, the topic also receives significant

attention in more specialized outlets focusing on resource policy, environmental management, and network technologies.

The presence of E3S Web of Conferences and AIP Conference Proceedings among the top ten publication sources demonstrates that conference contributions also play an important role in disseminating ideas and early-stage research. This reflects the rapidly developing nature of the field, where presenting research findings in scientific forums serves to accelerate the exchange of ideas and foster cross-institutional collaboration. Meanwhile, journals such as the Journal of Environmental Management, Environment, Development and Sustainability, and Energy Economics highlight an interdisciplinary focus on management, sustainable development policy, and energy economics that supports the green transition agenda.

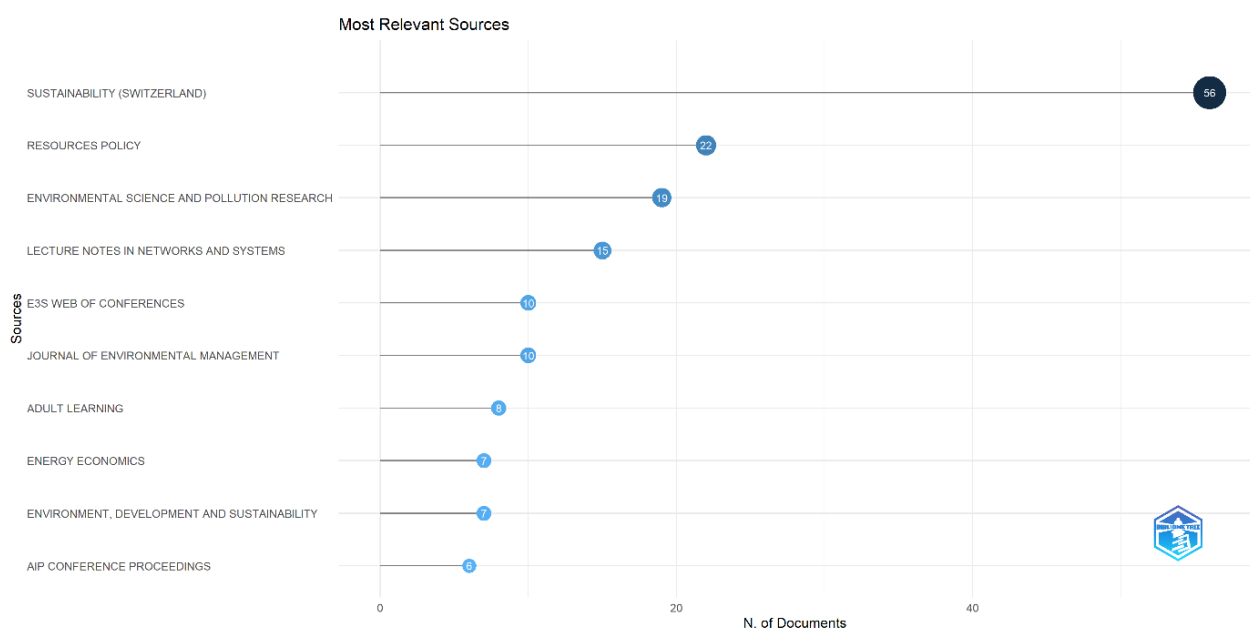


Figure 2. Most relevant source

The analysis of the most globally cited documents shows that key literature addressing the linkages between sustainable development, energy policy, and environmental quality has had a major influence in shaping the research agenda. The article by D'Amato (Journal of Cleaner Production) (D'Amato et al., 2017) ranks first with 779 citations, followed by Zhang (2021, Energy Policy) with 620 citations. Other significant works include Chaudhary (2018, Management of Environmental Quality) with 351 citations and Consoli (2016, Resources Policy) with 246 citations, both highlighting the transition toward environmentally friendly industrial practices and their implications for the labor market. Publications by Lin (2019, Energy Economics) and Swilling (2016, Journal of Environmental Policy and Planning) further reinforce the close relationship between energy economics and sustainable development policy, while more recent contributions such as Wei (2023, Environmental Impact Assessment Review) and Ali (2021, South African Journal of Science) have already entered the list, reflecting contemporary concerns with

energy policy impacts and regional adaptation. Even the classic work of Cai (2011, Energy) remains relevant, underscoring the durability of energy literature in sustainability discourse. As illustrated in Figure 3, this citation pattern indicates that the most influential documents serve not only as conceptual foundations but also as benchmarks guiding further studies on the role of education in fostering green skills and responding to the dynamics of the global labor market.

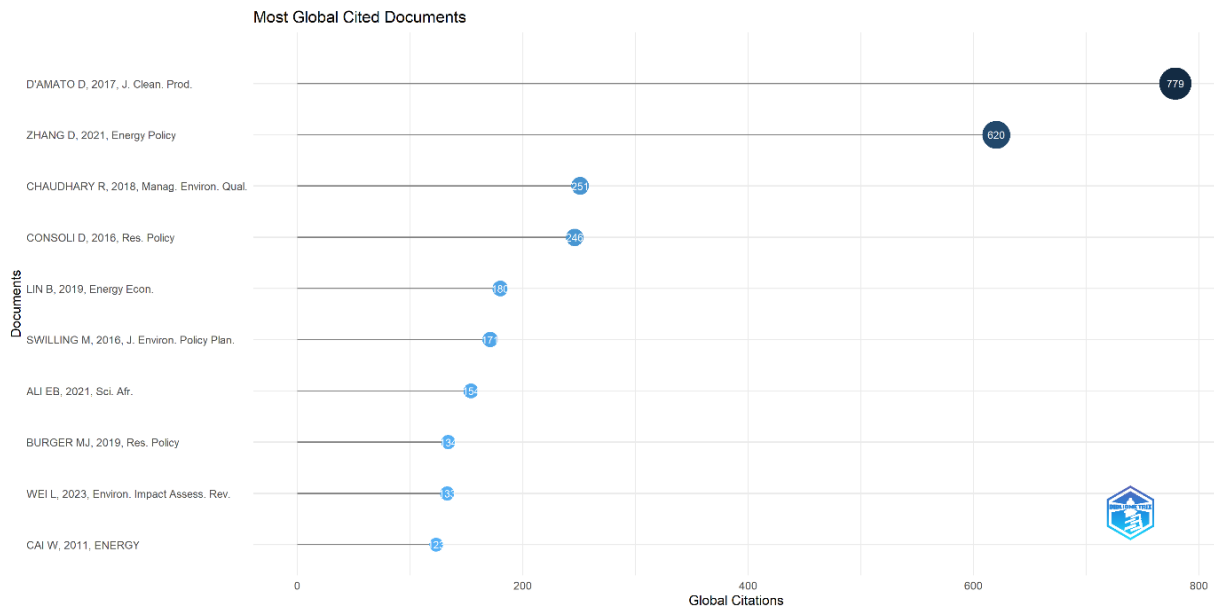


Figure 3. Most Cited Documents

In terms of citation performance, China dominates with a total of 2,884 citations, reaffirming its role as a global hub for both research and green transition policymaking. Following China are Finland (819 citations), South Africa (406 citations), and France (401 citations). Interestingly, contributions from developing countries such as India (96 citations) and Ghana (22 citations) have also started to appear, although their scale remains much smaller compared to advanced economies. As illustrated in Figure 4, this pattern reinforces the view that research in this field is still largely concentrated in the Global North, while developing countries need to strengthen their publication output and visibility to contribute more effectively to the formulation of scientific agendas and policy frameworks.

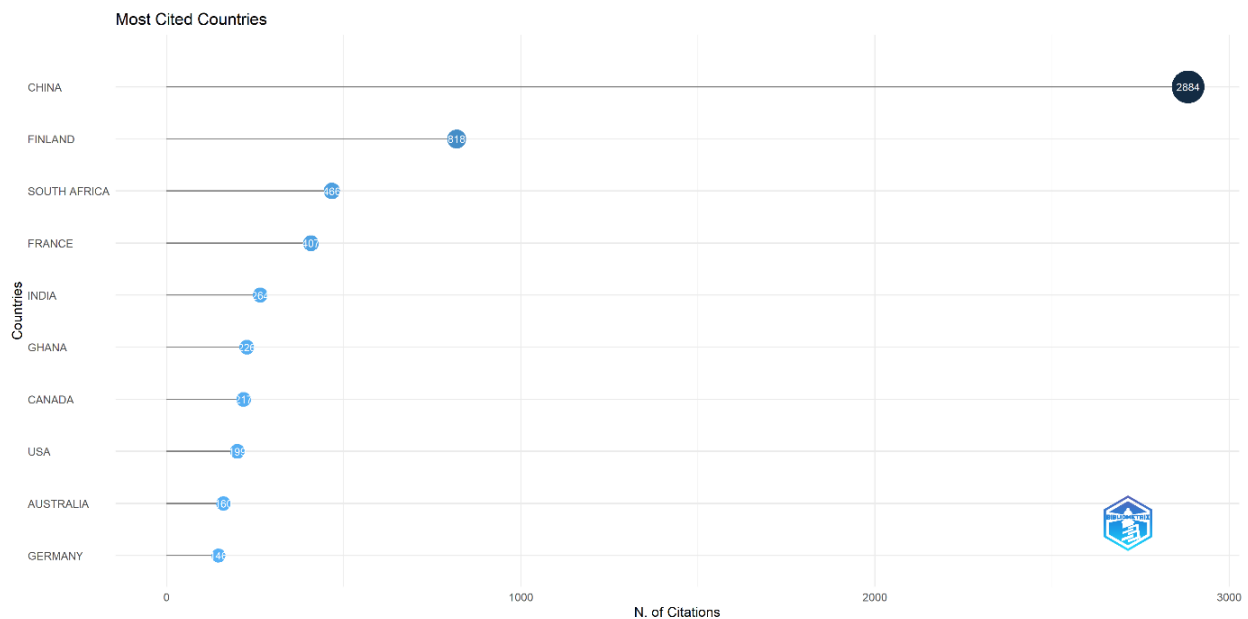


Figure 4. Most Cited Countries

This gap is also reflected in the literature, which highlights the dominance of developed country contexts in sustainability-oriented education research, while developing countries, including Indonesia, are still positioned as emerging contexts (Maharani, 2025; Sholehah et al., 2024). Thus, the distribution of publication sources and citation performance not only reflects scientific activity but also reveals structural imbalances in the global production and consumption of knowledge. This situation underscores the need for affirmative strategies to broaden the participation of developing countries in the academic ecosystem, particularly through strengthening international collaboration, expanding access to open publications, and integrating ESD into national research agendas (Adriana & Setiawan, 2021; Ilmi, 2021).

3. Authorship, Institutional, and Country Collaboration Networks

The analysis of the most relevant authors shows that contributions in the field of sustainability education and green jobs remain relatively dispersed. Marin Giovanni and Stroud Dean occupy the top positions with four publications each, while other authors such as Bin Kamin Yusri, Evans Claire, and Zhang Ming have produced only three documents. As illustrated in Figure 5, this distribution indicates that no single scholar has yet emerged as a dominant figure in the field. This characteristic is consistent with the multidisciplinary nature of the topic, which bridges education, energy policy, and green transition, leading research to be carried out more often within collaborative and cross-disciplinary frameworks rather than being concentrated in individual scholars (Bilqis et al., 2024; Budiarto et al., 2024).

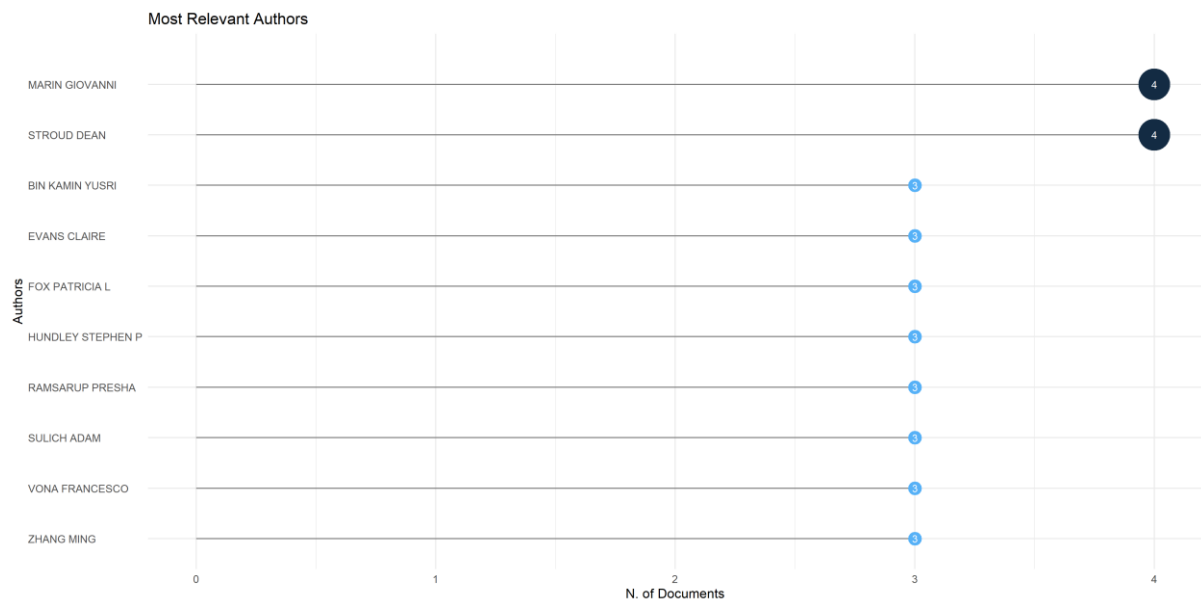


Figure 5. Most Relevant Authors

In terms of affiliations, the largest contribution comes from Heriot-Watt University with 11 articles, followed by several institutions with seven articles each, such as the Bucharest University of Economic Studies, Indiana University-Purdue University Indianapolis, and Universitas Pendidikan Indonesia. As illustrated in Figure 6, the presence of two Indonesian universities among the top affiliations—Universitas Pendidikan Indonesia and Universitas Indonesia—indicates that Indonesian academics are increasingly recognized within the global discourse on sustainability education and green skills. This finding is consistent with earlier observations that the contexts of Indonesia and Southeast Asia are beginning to be positioned as emerging research contexts (Maharani, 2025; Sholehah et al., 2024).

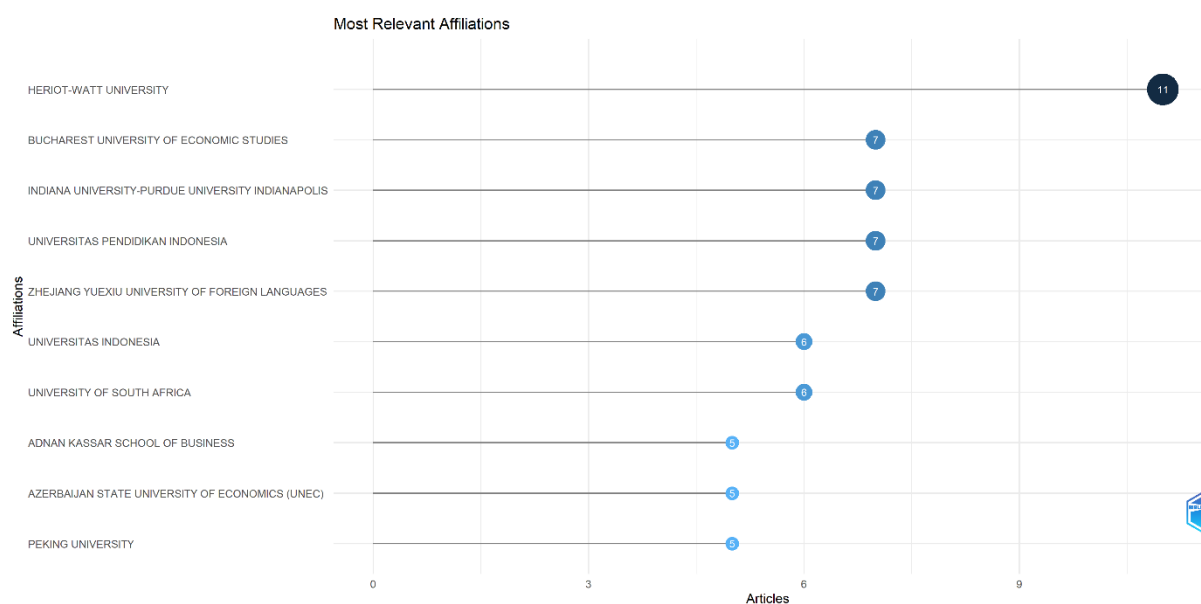


Figure 6. Most Relevant Affiliations

The international collaboration map shows China as the largest contributor, with nearly 150 publications, the majority of which are classified as single country publications (SCP). This reflects China's very strong domestic research capacity, although its level of international collaboration remains relatively limited. In contrast, the United States has a larger proportion of multiple country publications (MCP), reflecting a well-established tradition of international collaboration. As illustrated in Figure 7, Indonesia appears among the top three countries, alongside China and the United States, with a significant contribution, although most of its output is still in the form of SCP. This position presents an opportunity to strengthen international collaboration networks so that publications from Indonesia may achieve broader visibility and higher citation impact (Adriana & Setiawan, 2021; Ilmi, 2021).

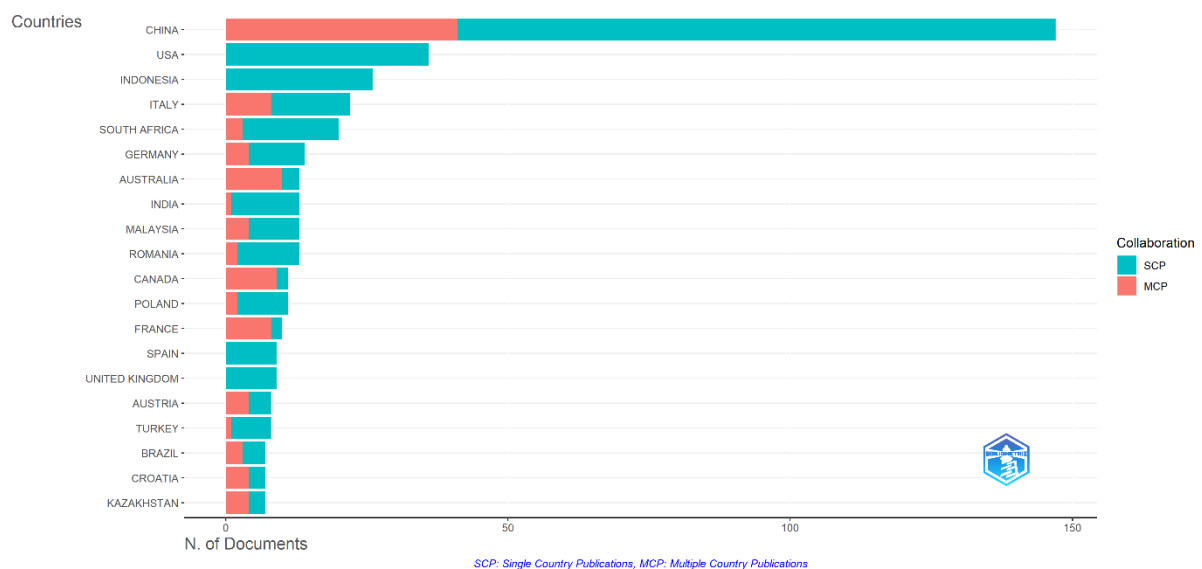


Figure 7. Corresponding Author's Countries

Overall, the patterns of authorship, institutional affiliation, and country collaboration indicate that this field is still in a consolidation stage, with contributions remaining fragmented yet steadily growing. China's dominance in the number of documents needs to be balanced by greater cross-country cooperation, particularly to bridge the gap between developed and developing contexts. Thus, institutional and international collaboration can serve as a key strategy to strengthen the integration of scientific findings into education policies and green labor market strategies at the global level (Fitriyanto & Triyono, 2023; Mutohhari et al., 2025).

4. Keyword Co-occurrence and Thematic Mapping

The keyword analysis shows that the terms "green economy" and "sustainable development" dominate the discourse, appearing most prominently both in the word cloud and in the co-occurrence network. These two terms represent the conceptual axis

that unites discussions on the linkage between education and the green transition. Other frequently occurring keywords include economic development, green development, sustainability, and environmental economics, which highlight the strong relationship between economic dimensions, education, and environmental policy. As illustrated in Figure 8, the presence of keywords such as education, higher education, and engineering education also indicates that formal education pathways, particularly higher education and vocational training, are increasingly recognized as strategic instruments in preparing green skills (Handayani et al., 2020; SetiAwan, 2017).



Figure 8. Word Cloud

The co-occurrence map reveals three main clusters. The first cluster (blue) focuses on green economy, sustainable development, and economic policy, which are connected to issues of energy, investment, and carbon emission. The second cluster (red) emphasizes sociodemographic aspects such as human, male, female, and adult, which are commonly found in studies employing social or public health perspectives. Meanwhile, the third cluster (green) features keywords such as engineering education, curricula, teaching, and students, reflecting an orientation toward pedagogical innovation and sustainability-based curriculum design. As illustrated in Figure 9, these three clusters underscore the multidimensionality of the research field, where education for sustainable development is linked not only to technical aspects but also to social values and pedagogy (Fauziah et al., 2024; Ismail et al., 2025).

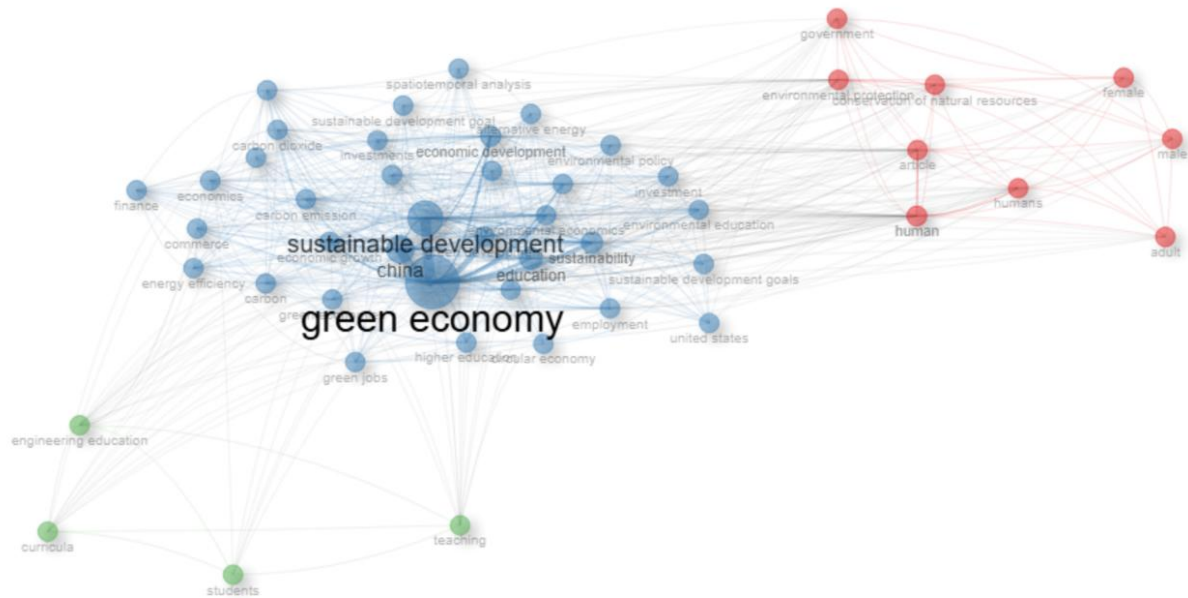


Figure 9. Co-occurrence Network

The results of the thematic mapping show that the themes “green economy” and “sustainable development” fall into the category of motor themes, indicating that they are both highly central and rapidly developing. The themes education, human, and article are in the basic themes quadrant, meaning that they are important but have not yet shown intensive development. In contrast, engineering education, green jobs, and curricula appear as emerging themes, topics that are still at an early stage but hold strong potential to grow into major research focuses in the future. As illustrated in Figure 10, this finding aligns with the literature emphasizing the need to strengthen vocational pathways and higher education curricula to meet the demands of the green labor market (Fitriyanto & Triyono, 2023; Mutohhari et al., 2025).

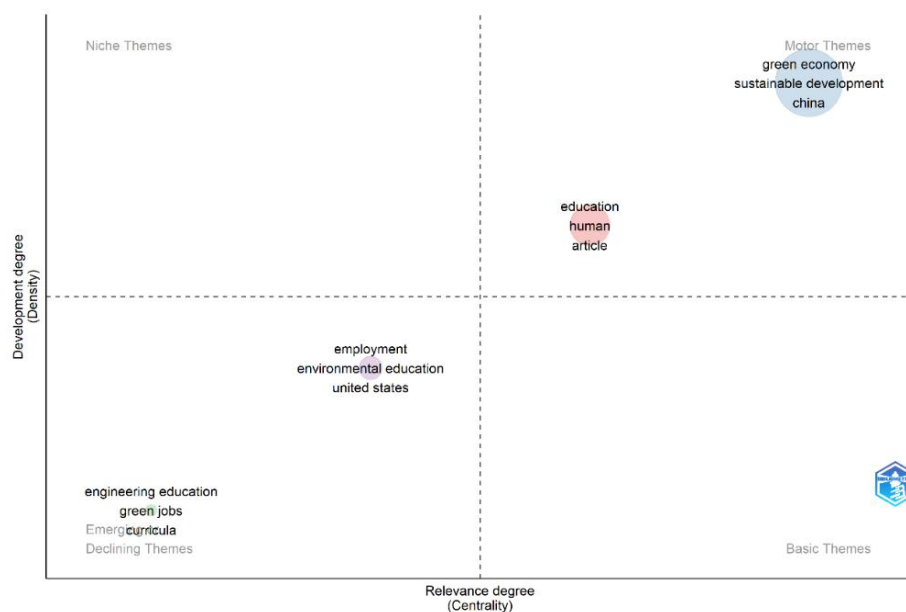


Figure 10. Thematic Map

Meanwhile, themes such as employment and environmental education appear as declining or transversal, suggesting that research in these areas may be reaching saturation or shifting toward more applied and contextual directions. This shift reflects the global discourse's growing emphasis on integrating green skills into the circular economy and renewable energy, rather than focusing solely on conventional environmental education. Accordingly, the thematic mapping highlights not only the current structure of knowledge but also the future trajectory of the field, especially the integration of curriculum and pedagogy into green economy transition agendas (Adriana & Setiawan, 2021; Ilmi, 2021).

5. Thematic Evolution Across Time

The cross-time thematic mapping highlights a gradual shift in research focus from narrower environmental issues toward broader agendas related to the green economy and sustainable development. During the early period of 2001–2008, research themes were still dominated by the keyword recycling, which functioned as a motor theme. As illustrated in Figure 12a, this suggests that the early discourse revolved primarily around waste management strategies and natural resource conservation. However, this approach remained largely technical and did not directly connect with the educational dimension.

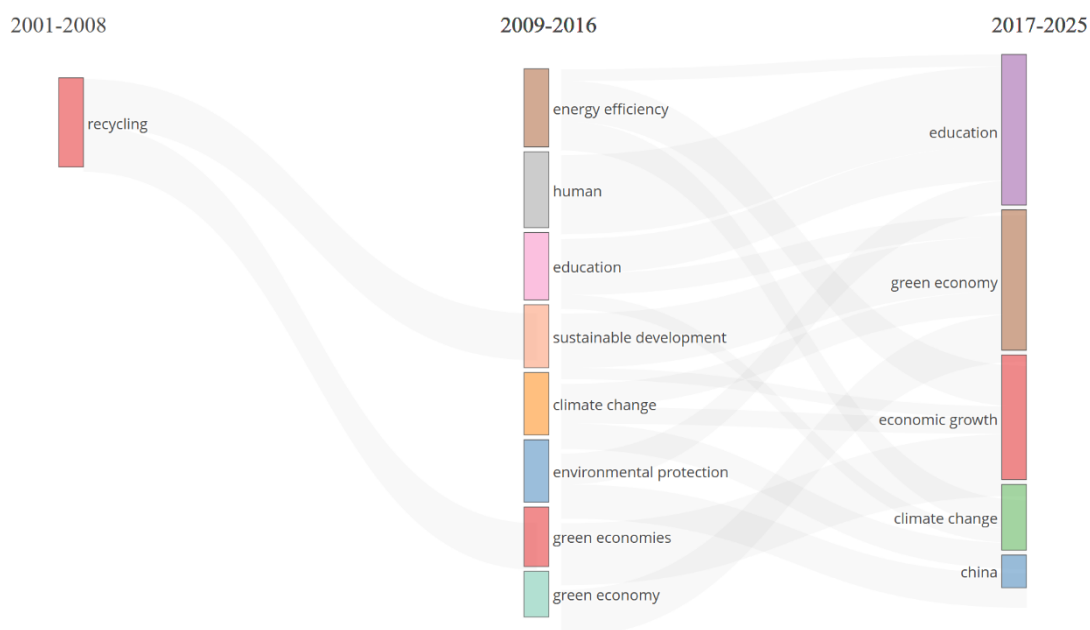


Figure 11. Thematic Evolution

Entering the 2009–2016 period, themes became more diversified with the emergence of keywords such as energy efficiency, education, sustainable development, climate change, and environmental protection. At this stage, sustainable development

began to occupy a central position, while education emerged as a crucial bridge linking environmental issues with broader social agendas. As shown in Figure 12b, these findings are consistent with the literature emphasizing the role of education in shaping climate awareness and sustainability competencies at both individual and institutional levels (Bilqis et al., 2024; Budiarto et al., 2024).

In the 2017–2025 period, research focus shifted more strongly toward green economy, economic growth, and China as key terms. This indicates that education for sustainable development is increasingly associated with the dynamics of the global green economy and specific geopolitical contexts. At the same time, education remained a persistent theme, signaling consistent academic attention to pedagogical dimensions in the green transition. As depicted in Figure 12c, this trajectory underscores how educational pathways continue to be central in preparing green skills within the broader framework of sustainable development (Fitriyanto & Triyono, 2023; Mutohhari et al., 2025).

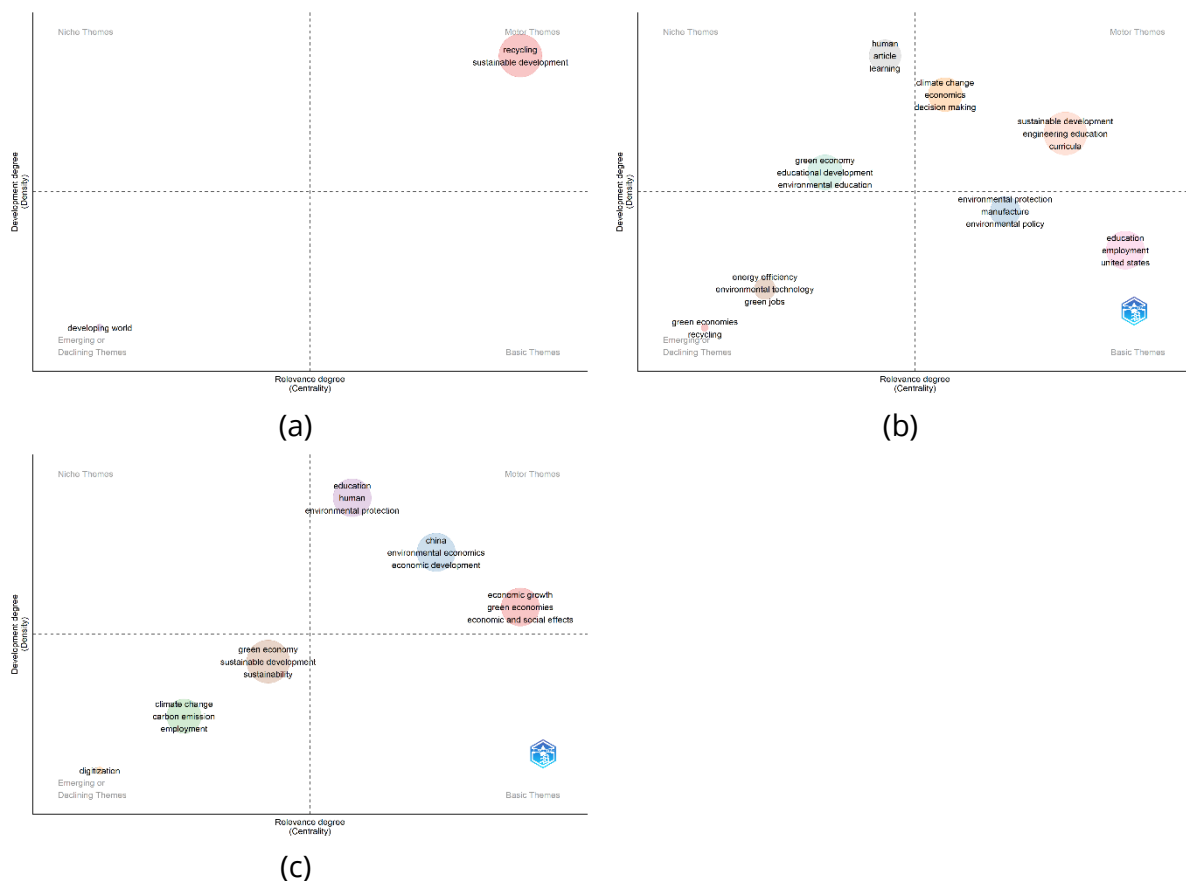


Figure 12. (a) Thematic Evolution Map 1, (b), Thematic Evolution Map 2, (b), Thematic Evolution Map 3

Overall, this thematic evolution illustrates a shift from an initial orientation grounded in technical conservation toward a more comprehensive understanding of sustainable development and the green economy. This shift also signifies a clearer

integration between economic policy, social dynamics, and educational pathways, such that recent research increasingly emphasizes how education can function as a catalyst for the green transition and the provision of green jobs (Maharani, 2025; Sholehah et al., 2024).

6. Linking ESD and Green Jobs

The bibliometric results confirm that the intersection between Education for Sustainable Development (ESD) and green jobs has become a rapidly expanding field of study. The surge in publications after 2019 demonstrates growing academic attention to the green economy transition, consistent with earlier research emphasizing the importance of energy policy and resource efficiency in sustainable development (D'Amato et al., 2017; D. Zhang et al., 2021). Moreover, major themes such as sustainable development and green economy function not only as research drivers but also as conceptual frameworks connecting social, economic, and educational dimensions within the global sustainability agenda (Burger et al., 2019; Chaudhary & Bisai, 2018).

From a geographical perspective, citation results reveal the dominance of developed countries, particularly China, the United States, and Finland. Nevertheless, contributions from developing countries are emerging, with increasing studies from South Africa, India, and Indonesia. In the Indonesian context, notable progress is visible through the involvement of Universitas Pendidikan Indonesia and Universitas Indonesia in reputable publications, which highlight the implementation of green curricula and vocational skills aligned with labor market demands (Maharani, 2025; Sholehah et al., 2024). This aligns with local literature stressing the importance of TVET and 6R-based learning in preparing a workforce for green employment (Handayani et al., 2020; SetiAwan, 2017).

Several conceptual challenges, however, must be acknowledged. The definition of green jobs remains contested and is often vulnerable to market bias or greenwashing. Previous studies note that gaps between policy orientation and educational implementation can restrict the tangible impact of ESD programs (Hastuti & Purnama, 2024; Subyantoro et al., 2022). Furthermore, normative and value-based dimensions play an equally important role, especially in the context of religion-based or socially grounded education, which shapes pro-environmental behavior (Fauziah et al., 2024; Ismail et al., 2025). Thus, the integration of ESD curricula cannot be limited to technical aspects but must also incorporate ethical, cultural, and technological dimensions.

Research gaps remain evident. Most studies rely on single-case designs and focus heavily on developed countries, limiting cross-context generalizability (Acciaioli & Afiff, 2018; Hamid & Lubis, 2024). Methodologically, there is also a scarcity of longitudinal studies that evaluate the sustained impact of ESD on green labor markets. Future research opportunities include cross-country comparative studies among developing

nations, integration of digital technologies in green learning, and long-term policy evaluations to assess the extent to which education graduates are entering green labor markets (Lin & Zhu, 2019; Swilling et al., 2016; M. Zhang et al., 2023). Accordingly, ESD can be increasingly positioned as a catalyst for transformation toward a green economy that is oriented not only to growth but also to social justice and long-term sustainability.

Conclusion

This study provides a comprehensive overview of the intersection between Education for Sustainable Development (ESD) and green jobs through bibliometric analysis. The results reveal a significant increase in publications after 2019, highlighting the growing academic and policy attention to education as a driver of the green economy transition. Core themes such as sustainable development and green economy dominate the field, while emerging topics like engineering education, green jobs, and curricula show strong potential for future research.

Geographically, the field is still dominated by advanced economies such as China, the United States, and Finland, although contributions from emerging contexts, including Indonesia, are increasingly visible. This indicates both a persistent imbalance in knowledge production and opportunities for broader participation from developing regions.

Key challenges include the lack of consensus on defining green jobs, risks of greenwashing, and gaps between curricular design and actual labor market demands. Future research should prioritize comparative cross-country studies, curriculum innovation, and longitudinal assessments to ensure that ESD effectively contributes to building green skills and promoting an inclusive and just transition toward sustainability.

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