

The Structural and Thematic Evolution of Education for Sustainable Development Research in Asia: A Bibliometric and Network Analysis

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ABSTRACT

Despite growing global commitment to the Sustainable Development Goals (SDGs), the development of Education for Sustainable Development (ESD) research remains uneven across regions, with limited understanding of its structural and thematic dynamics in Asia. Existing studies are largely descriptive and lack theoretical integration, particularly in explaining how knowledge production, collaboration, and thematic evolution interact within regional research systems. This study addresses this gap by examining the structural and thematic evolution of ESD research in Asia. Using a theory-informed bibliometric and network analysis, the study analyzes 1,700 Scopus-indexed journal articles published between 2019 and 2023. The analytical framework integrates performance indicators, coauthorship network analysis, and keyword co-occurrence mapping. The results reveal three key patterns: (1) a high concentration of research output in a small number of countries and institutions, indicating structural asymmetry; (2) moderately connected but highly modular collaboration networks, suggesting fragmented knowledge diffusion mediated by central actors; and (3) a thematic structure anchored in sustainability and SDGs, alongside the rapid emergence of digital learning and artificial intelligence. These findings suggest that ESD research in Asia is evolving as a semi-integrated knowledge ecosystem shaped by uneven research capacity and global policy influence. This study advances the literature by integrating structural, relational, and thematic dimensions within a theory-informed bibliometric framework. The findings provide practical implications for strengthening regional collaboration and aligning digital innovation with the transformative goals of sustainability education.

Keywords: *education for sustainable development, bibliometric analysis, science mapping, knowledge diffusion, sustainable development goals, digital learning, artificial intelligence, asia.*

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INTRODUCTION

Despite sustained global commitments to the Sustainable Development Goals (SDGs), progress toward achieving inclusive and equitable quality education remains uneven and structurally constrained.¹ Recent global assessments indicate persistent disparities in access, quality, and learning outcomes, exacerbated by the long-term effects of the COVID-19 pandemic and widening socio-economic inequalities.² These conditions underscore the limitations of conventional education systems in addressing complex and interconnected sustainability challenges. Consequently, education is increasingly reconceptualized not merely as a mechanism for knowledge transmission but as a transformative driver capable of enabling systemic change toward sustainable development.

Within this evolving context, Education for Sustainable Development (ESD) has emerged as a central framework linking educational transformation with sustainability transitions. ESD emphasizes the development of key competencies—including systems thinking, critical reflection, and anticipatory decision-making—that enable individuals to respond to complex global challenges.³ It also reflects a broader paradigmatic shift from content-based instruction toward competency-oriented and transformative learning approaches.⁴ As such, ESD is increasingly positioned as a critical mechanism for advancing SDG 4 while supporting broader sustainability goals.

A rapid expansion of scholarly output across disciplines has accompanied the growing importance of ESD. Bibliometric evidence indicates a significant increase in publications on sustainability education, particularly since 2019, reflecting intensified academic engagement with sustainability transitions.⁵ At the same time, the thematic scope of ESD research has diversified, with increasing attention to digital learning, interdisciplinary approaches, and

¹ Joseph Friedman et al., “Measuring and Forecasting Progress towards the Education-Related SDG Targets,” *Nature* 580, no. 7805 (April 30, 2020): 636–39, <https://doi.org/10.1038/s41586-020-2198-8>; UNESCO, *Global Education Monitoring Report 2020*, Global Education Monitoring Report (UN, 2020), <https://doi.org/10.18356/2ddb782c-en>; Marubini Christinah Sadiki, “Promoting Inclusive and Equitable Quality Education Through Human Rights to Achieve Sustainable Development Goal 4,” *Educational Administration: Theory and Practice*, 2024, <https://doi.org/10.53555/kuey.v30i11.8324>.

² UNESCO, *The Sustainable Development Goals Report 2022*, The Sustainable Development Goals Report (United Nations, 2022), <https://doi.org/10.18356/9789210018098>.

³ N. Voulvoulis et al., “Systems Thinking as a Paradigm Shift for Sustainability Transformation,” *Global Environmental Change* 75 (July 2022): 102544, <https://doi.org/10.1016/j.gloenvcha.2022.102544>; Albert Zeyer, “Teaching Two-Eyed Seeing in Education for Sustainable Development: Inspirations from the Science|Environment|Health Pedagogy in Pandemic Times,” *Sustainability* 14, no. 10 (May 23, 2022): 6343, <https://doi.org/10.3390/su14106343>.

⁴ Adesuwa Vanessa Agbedahin, “Sustainable Development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, Efficacy, Eminence, and Future,” *Sustainable Development* 27, no. 4 (July 21, 2019): 669–80, <https://doi.org/10.1002/sd.1931>; Jorge Alberto Vargas-Merino, Cristian Armando Rios-Lama, and Miguel Humberto Panez-Bendezú, “Critical Implications of Education for Sustainable Development in HEIs - A Systematic Review through the Lens of the Business Science Literature,” *The International Journal of Management Education* 22, no. 1 (March 2024): 100904, <https://doi.org/10.1016/j.ijme.2023.100904>.

⁵ Entang Entang et al., “Research Trends About Education for Sustainable Development (ESD) in Science Learning: A Bibliometric Analysis During 2014-2024,” *Jurnal Pendidikan MIPA* 25, no. 3 (2024): 1317–28, <https://doi.org/10.23960/jpmipa/v25i3.pp1317-1328>; Mohamed Ali Osman, Abdirahman Ahmed Sheikh Farah, and Abdirahman Ibrahim Abdi, “A Bibliometric Analysis of Sustainable Development Research in Higher Education Institutions (HEIs): Key Trends, Global Collaborations and Influential Contributions (2015–2023),” *Cogent Education* 12, no. 1 (December 31, 2025), <https://doi.org/10.1080/2331186X.2025.2490436>.

sustainability competencies.⁶ This expansion suggests that the field is evolving toward greater complexity and integration.

However, despite this growth, the field remains characterized by several critical limitations. First, existing bibliometric studies are predominantly descriptive, focusing on publication trends and citation patterns without adequately explaining the structural mechanisms underlying knowledge production.⁷ Second, theoretical integration remains limited, with few studies linking empirical bibliometric findings to broader explanatory frameworks such as knowledge diffusion or scientific network theory. Third, the interaction between global policy agendas and regional research systems remains insufficiently explored, particularly in non-Western contexts.

These limitations are especially pronounced in regional analyses. Most existing studies adopt a global perspective that obscures regional heterogeneity in research capacity, collaboration dynamics, and thematic priorities. Asia represents a particularly critical yet underexplored context in this regard. As the most populous region globally and a major driver of economic and educational expansion, Asia encompasses diverse national systems characterized by uneven research capacity and differentiated policy trajectories. These conditions create a complex knowledge ecosystem in which processes of concentration, diffusion, and fragmentation coexist, shaping the evolution of ESD scholarship.

Furthermore, the post-2019 period has introduced unprecedented transformations in education systems worldwide. The COVID-19 pandemic accelerated the adoption of digital technologies, reshaped pedagogical practices, and intensified the integration of online and hybrid learning environments. Simultaneously, sustainability challenges—particularly climate change and socio-economic inequality—have become more urgent. Recent studies indicate that ESD is increasingly integrating digital innovation and new pedagogical approaches, reflecting a shift toward technologically mediated sustainability education.⁸ However, evidence also suggests that ESD implementation remains uneven, highlighting persistent gaps between policy aspirations and institutional practices.⁹

To address these gaps, bibliometric and network-based approaches provide a robust analytical framework. Bibliometric analysis enables systematic evaluation of scientific production and impact, while network analysis reveals the relational structures through

⁶ Entang et al., "Research Trends About Education for Sustainable Development (ESD) in Science Learning: A Bibliometric Analysis During 2014-2024"; Elvia Ivada, "Education For Sustainable Development in Preservice Teacher Program: A Bibliometric Method," *IJORER: International Journal of Recent Educational Research* 5, no. 5 (September 30, 2024): 1290–1310, <https://doi.org/10.46245/ijorer.v5i5.689>.

⁷ Chuang Yang and Qi Xiu, "A Bibliometric Review of Education for Sustainable Development, 1992–2022," *Sustainability* 15, no. 14 (July 10, 2023): 10823, <https://doi.org/10.3390/su151410823>.

⁸ Mestawot Beyene Tafese and Erika Kopp, "Education for Sustainable Development: Analyzing Research Trends in Higher Education for Sustainable Development Goals through Bibliometric Analysis," *Discover Sustainability* 6, no. 1 (January 23, 2025): 51, <https://doi.org/10.1007/s43621-024-00711-7>; Albert Zeyer, "Scientific Holism: A Synoptic ('Two-Eyed Seeing') Approach to Science Transfer in Education for Sustainable Development, Tested with Pre-Service Teachers," *Sustainability* 16, no. 6 (March 8, 2024): 2279, <https://doi.org/10.3390/su16062279>.

⁹ Mariem Fekih Zguir, Sana Dubis, and Muammer Koç, "Embedding Education for Sustainable Development (ESD) and SDGs Values in Curriculum: A Comparative Review on Qatar, Singapore and New Zealand," *Journal of Cleaner Production* 319 (October 2021): 128534, <https://doi.org/10.1016/j.jclepro.2021.128534>.

which knowledge is produced and disseminated. These approaches are particularly useful for mapping complex and rapidly evolving research fields such as ESD, where thematic diversification and structural fragmentation pose significant analytical challenges.¹⁰

However, the explanatory value of such approaches depends on their integration with theoretical perspectives. This study, therefore, draws on three complementary lenses. First, knowledge diffusion theory conceptualizes research fields as systems in which ideas circulate through collaboration networks and citation flows.¹¹ Second, scientific network theory emphasizes the role of structural configurations—such as centrality and modularity—in shaping the development of research domains. Third, policy transfer theory explains how global agendas, particularly the SDGs, influence national research priorities and institutional practices.¹² Together, these perspectives enable a systemic interpretation of ESD scholarship as a dynamic and evolving knowledge ecosystem.

Against this backdrop, the present study conducts a systematic bibliometric and network analysis of ESD research in Asian countries during the period 2019–2023. Specifically, the study addresses the following research questions: (1) What structural patterns characterize the production and impact of ESD research in Asia? (2) How do collaboration networks shape knowledge diffusion within the region? (3) How have thematic priorities evolved in response to global and regional transformations? Moreover, (4) What structural and thematic asymmetries persist within the field?

This study makes three key contributions. First, it provides a regionally grounded and temporally focused mapping of ESD research during a period of accelerated educational transformation. Second, it advances bibliometric analysis beyond descriptive mapping by integrating performance indicators with network structure and thematic evolution. Third, it proposes a theoretically informed framework linking policy framing, knowledge diffusion, and thematic transformation, offering a systemic explanation of how sustainability-oriented educational research evolves within a regional context.

METHOD

This study employed a theory-informed bibliometric and science-mapping design to examine the structural and thematic evolution of Education for Sustainable Development (ESD) research in Asia. Bibliometric research is well-suited to mapping large publication corpora, identifying influential actors, and capturing the intellectual and conceptual structure of a field; however, it should be treated as complementary to, rather than a

¹⁰ Naveen Donthu et al., “How to Conduct a Bibliometric Analysis: An Overview and Guidelines,” *Journal of Business Research* 133 (September 2021): 285–96, <https://doi.org/10.1016/j.jbusres.2021.04.070>; Nees Jan van Eck and Ludo Waltman, “Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping,” *Scientometrics* 84, no. 2 (August 31, 2010): 523–38, <https://doi.org/10.1007/s11192-009-0146-3>.

¹¹ Ying Ding, “Scientific Collaboration and Endorsement: Network Analysis of Coauthorship and Citation Networks,” *Journal of Informetrics* 5, no. 1 (January 2011): 187–203, <https://doi.org/10.1016/j.joi.2010.10.008>.

¹² David P. Dolowitz and David Marsh, “Learning from Abroad: The Role of Policy Transfer in Contemporary Policy-Making,” *Governance* 13, no. 1 (January 17, 2000): 5–23, <https://doi.org/10.1111/0952-1895.00121>.

substitute for, systematic literature review approaches.¹³ Accordingly, the present study combined performance analysis with science mapping in order to examine publication output, collaboration structures, and thematic change.

Data source and retrieval

The bibliographic data were retrieved from the Scopus database on 10 December 2023 using the following query:

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(TITLE-ABS-KEY ("education for sustainable development")) AND (PUBYEAR > 2018 AND PUBYEAR < 2024) AND (DOCTYPE (ar)) AND (LANGUAGE (English)) AND (AFFILCOUNTRY (China OR Indonesia OR India OR Malaysia OR Japan OR South Korea OR Thailand OR Philippines OR Vietnam OR Pakistan OR Bangladesh OR Singapore OR Sri Lanka OR Nepal OR Cambodia OR Myanmar OR Laos OR Brunei OR Mongolia))
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The search was restricted to peer-reviewed journal articles published between 2019 and 2023, written in English, and with at least one author affiliated with an Asian institution. The initial search yielded 1,720 records; after screening for duplicates and incomplete metadata, 1,700 articles were retained for analysis.

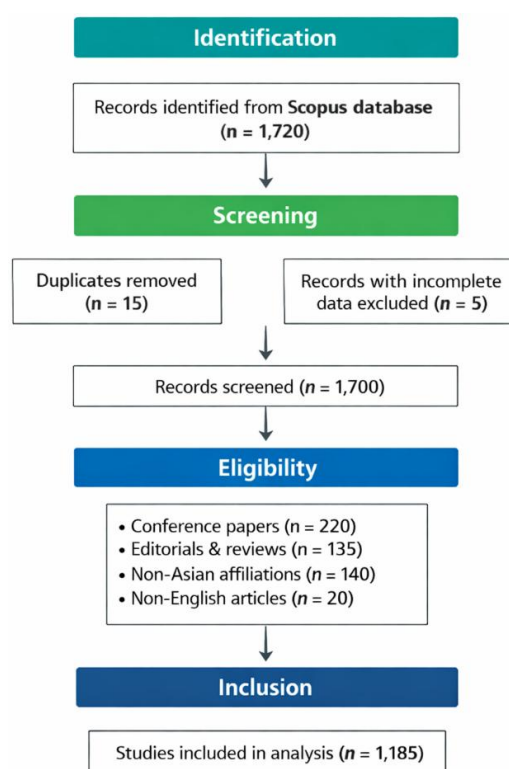


Figure 1. Screening and eligibility process of the bibliometric dataset.

Screening and eligibility criteria

The screening logic followed a transparent identification–screening–eligibility–inclusion sequence aligned with PRISMA 2020 reporting principles, adapted for bibliometric

¹³ Donthu et al., “How to Conduct a Bibliometric Analysis: An Overview and Guidelines”; Debmalya Mukherjee et al., “Guidelines for Advancing Theory and Practice through Bibliometric Research,” *Journal of Business Research* 148 (September 2022): 101–15, <https://doi.org/10.1016/j.jbusres.2022.04.042>; Oğuzhan Öztürk, Ridvan Kocaman, and Dominik K. Kanbach, “How to Design Bibliometric Research: An Overview and a Framework Proposal,” *Review of Managerial Science* 18, no. 11 (November 6, 2024): 3333–61, <https://doi.org/10.1007/s11846-024-00738-0>.

retrieval rather than intervention-focused synthesis. Inclusion criteria were: (1) journal articles, (2) English language, (3) publication years 2019–2023, and (4) at least one Asian affiliation. Exclusion criteria were: conference papers, editorials, reviews, records with incomplete bibliographic metadata, and duplicate entries. This approach improves reproducibility and makes the selection process auditable.

Data cleaning and preprocessing

Prior to analysis, the metadata were cleaned and standardized to improve the reliability of the resulting maps. Author names were harmonized where variant forms were identifiable, institutional names were standardized, and author keywords were manually and semi-automatically merged when synonyms, abbreviations, or singular–plural variants referred to the same concept. Generic or non-informative keywords were removed to reduce noise in the co-occurrence analysis. Records lacking essential metadata were excluded from specific network procedures when necessary. This preprocessing is consistent with recent guidance on cleaning bibliometric datasets and combining multiple bibliometric tools in a single workflow.¹⁴

Analytical procedures

The analytical workflow consisted of five stages: data preparation, performance analysis, network construction, thematic mapping, and robustness checking. Performance analysis was conducted in R using the Bibliometrix/Biblioshiny package, which supports the recommended bibliometric workflow for large-scale science mapping.¹⁵ VOSviewer was used for visualizing coauthorship, co-occurrence, and co-citation networks because it is designed specifically for constructing and displaying large bibliometric maps in an interpretable format.¹⁶ These tools are widely recommended in bibliometric research because they facilitate the analysis of publication patterns, collaboration structures, and thematic relations at scale.¹⁷

Performance indicators included annual publication growth, total citations, average citations per document, and the most productive and influential countries, institutions, journals, and authors. Collaboration analysis was conducted through country-level and institutional coauthorship networks. Fractional counting was applied in collaboration analysis to reduce inflation bias associated with multi-authored papers. Network density, degree centrality, betweenness centrality, and modularity were computed to assess cohesion, brokerage, and clustering. Keyword co-occurrence analysis was used to identify thematic clusters, with a minimum occurrence threshold of 10. Citation and co-citation

¹⁴ Weng Marc Lim, Satish Kumar, and Naveen Donthu, “How to Combine and Clean Bibliometric Data and Use Bibliometric Tools Synergistically: Guidelines Using Metaverse Research,” *Journal of Business Research* 182 (September 2024): 114760, <https://doi.org/10.1016/j.jbusres.2024.114760>.

¹⁵ Massimo Aria and Corrado Cuccurullo, “Bibliometrix : An R-Tool for Comprehensive Science Mapping Analysis,” *Journal of Informetrics* 11, no. 4 (November 2017): 959–75, <https://doi.org/10.1016/j.joi.2017.08.007>.

¹⁶ van Eck and Waltman, “Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping.”

¹⁷ Donthu et al., “How to Conduct a Bibliometric Analysis: An Overview and Guidelines”; Ivan Zupic and Tomaž Čater, “Bibliometric Methods in Management and Organization,” *Organizational Research Methods* 18, no. 3 (July 22, 2015): 429–72, <https://doi.org/10.1177/1094428114562629>.

analyses were conducted to identify influential works and to reveal the intellectual base of the field, with a minimum citation threshold of 20 for network inclusion.

Temporal and robustness analysis

To capture field evolution over time, publications were analyzed in annual slices from 2019 to 2023. Time-sliced keyword networks were used to identify stable, emerging, and declining themes across the study window. Robustness checks were conducted by varying the minimum keyword threshold from 10 to 8 and 12 and by excluding 2023 publications to account for citation time-lag bias. The cluster structure remained stable across these perturbations, with adjusted Rand index values of 0.86 and 0.82 relative to the baseline threshold, and the top country rankings by centrality remained unchanged. Network density and modularity also varied only marginally. Such sensitivity testing is methodologically important because bibliometric clustering can be affected by preprocessing and threshold choices.¹⁸

The study is limited by its exclusive reliance on Scopus-indexed, English-language journal articles. This may underrepresent locally published scholarship, non-English outputs, and documents indexed in other databases. In addition, citation-based indicators are subject to exposure-time bias, particularly for recently published work. These limitations do not invalidate the analysis, but they delimit its scope and should be considered when interpreting the results.

RESULTS AND DISCUSSION

Results

Publication and Citation Structure

A total of 1,700 peer-reviewed journal articles met the inclusion criteria for this study. Annual publication output demonstrated a substantial upward trend over the study period, increasing from 2019 to a peak in 2022, followed by a moderate decline in 2023. This pattern suggests a phase of rapid expansion during the mid-period, followed by stabilization in the most recent year.

Table 1. Summary of dataset and citation metrics (2019–2023)

Metric	Value
Total documents	1,700
Total authors	4,623
Total sources (journals)	497
Total citations	13,600
Average citations per document	8.0
Annual growth rate (%)	22.68

The dataset accumulated approximately 13,600 citations at the time of data extraction, yielding an average of 8.0 citations per document. Citation distribution was highly

¹⁸ Lim, Kumar, and Donthu, "How to Combine and Clean Bibliometric Data and Use Bibliometric Tools Synergistically: Guidelines Using Metaverse Research"; Öztürk, Kocaman, and Kanbach, "How to Design Bibliometric Research: An Overview and a Framework Proposal."

skewed, with the majority of publications receiving fewer than 10 citations, while a small proportion of highly cited articles accounted for a disproportionate share of total citations.

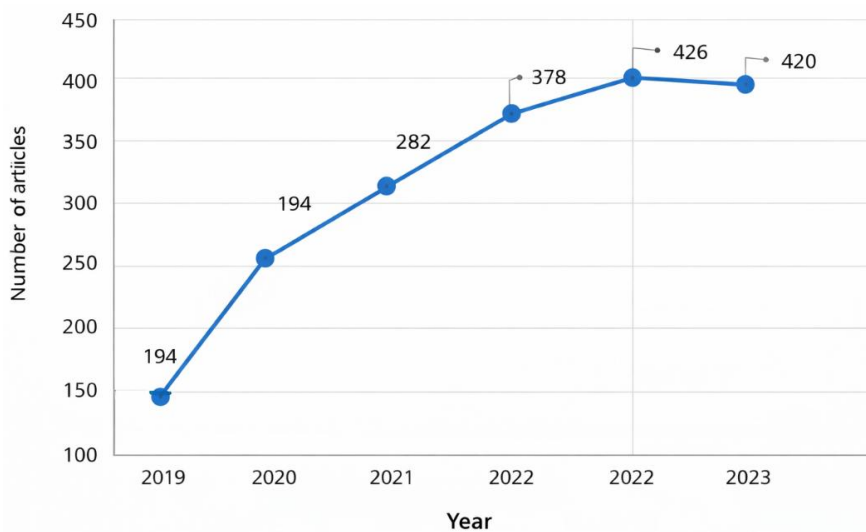


Figure 2. Annual publication of ESD trend in Asia (2019-2023)

This pattern is characteristic of emerging and rapidly expanding research fields, where citation accumulation is unevenly distributed across publications. The results indicate that ESD research in Asia has experienced substantial growth during the 2019–2023 period, accompanied by increasing but uneven citation impact across the dataset.

Leading Contributors and Publication Outlets

Publications in the dataset were affiliated with 25 Asian countries, reflecting a geographically diverse research landscape. However, knowledge production was highly concentrated among a limited number of countries. China accounted for the largest share of publications (30.6%), followed by India (15.3%) and Indonesia (8.8%). Together, the top ten countries contributed more than 85% of total output, indicating a strong concentration of research activity within a relatively small group of countries.

Table 2. Leading countries in ESD research (2019–2023)

Rank	Country	Publications	% Total
1	China	520	30.6%
2	India	260	15.3%
3	Indonesia	150	8.8%
4	Malaysia	120	7.1%
5	South Korea	100	5.9%
6	Japan	95	5.6%
7	Philippines	60	3.5%
8	Thailand	55	3.2%
9	Vietnam	50	2.9%
10	Singapore	40	2.4%

Table 3. Top 10 journals publishing ESD research with citation impact (2019–2023)

Rank	Journal Title	Publications	% of Total	Total Citations	Avg. Citations per Article	Journal Positioning
1	Sustainability	210	12.4%	4,528	21.56	Dominant multidisciplinary outlet
2	International Journal of Sustainability in Higher Education	38	2.24%	304	8.00	Specialized higher education focus
3	Sustainable Development	22	1.29%	732	33.27	High-impact sustainability journal
4	Environment, Development and Sustainability	21	1.24%	257	12.24	Policy-oriented research
5	Resources Policy	21	1.24%	142	6.76	Economic–resource perspective
6	Journal of Teacher Education for Sustainability	18	1.06%	81	4.50	Pedagogical specialization
7	Social Indicators Research	13	0.76%	133	10.23	Social impact and indicators
8	Education Sciences	12	0.71%	58	4.83	Education-focused outlet
9	International Journal of Sustainable Development and Planning	12	0.71%	46	3.83	Applied sustainability research
10	Frontiers in Education	11	0.65%	5	0.45	Emerging education platform

Institutional productivity analysis revealed a similar pattern of concentration. Although 480 institutions were represented in the dataset, the top 10 institutions accounted for approximately one-third of total publications. This suggests that institutional research capacity plays a significant role in shaping the distribution of ESD scholarship within the region.

In terms of publication outlets, the dataset was distributed across a wide range of journals, although a small number of journals accounted for a disproportionately large share of publications. The journal *Sustainability* emerged as the most prominent outlet, followed by several specialized journals in sustainability and education. This pattern indicates a partial centralization of publication channels within the field. These findings reveal a structurally uneven landscape of knowledge production, characterized by concentration at both country and institutional levels.

Collaboration Networks

(1). Country-Level Collaboration

The country-level co-authorship network consisted of 25 nodes and 36 links, with a network density of 0.12. This relatively low density indicates limited overall connectivity

among countries, suggesting that collaboration remains moderate rather than fully integrated.

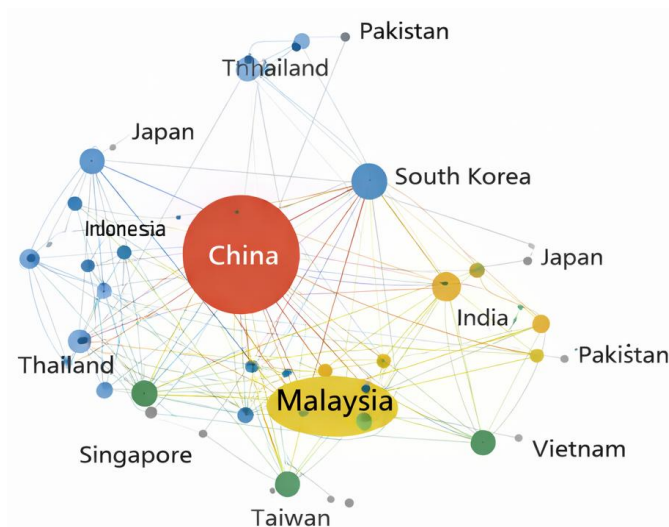


Figure 3. Country-level co-authorship network in Asian ESD research (2019–2023). Node size represents publication output, and link strength indicates collaboration intensity. The network exhibits low density (0.12), with China, India, and Malaysia occupying central positions, and a modular structure (0.42) indicating clustered collaboration patterns.

Centrality analysis identified China, India, and Malaysia as the most prominent actors in the network, based on degree and betweenness centrality measures. These countries occupy structurally central positions, indicating their importance in facilitating cross-national collaboration.

The modularity score of 0.42 and the presence of four distinct clusters indicate a partially fragmented network structure, where collaboration tends to occur within subgroups rather than across the entire network. Despite this fragmentation, the largest connected component included the majority of countries, suggesting the presence of a shared collaborative core.

(2). Institutional Collaboration

At the institutional level, the network included 480 nodes and 1,100 edges, with a low density of 0.0096 and relatively high modularity (0.61). This indicates a more fragmented structure compared to the country-level network, with collaboration concentrated within clusters of closely connected institutions.

Several institutions exhibited high degree and betweenness centrality, indicating their role as key connectors within the network. The presence of such institutions suggests that collaboration is mediated by a limited number of highly connected actors rather than evenly distributed across the network. The collaboration analysis indicates that ESD research in Asia is characterized by moderate international integration but significant structural fragmentation, particularly at the institutional level.

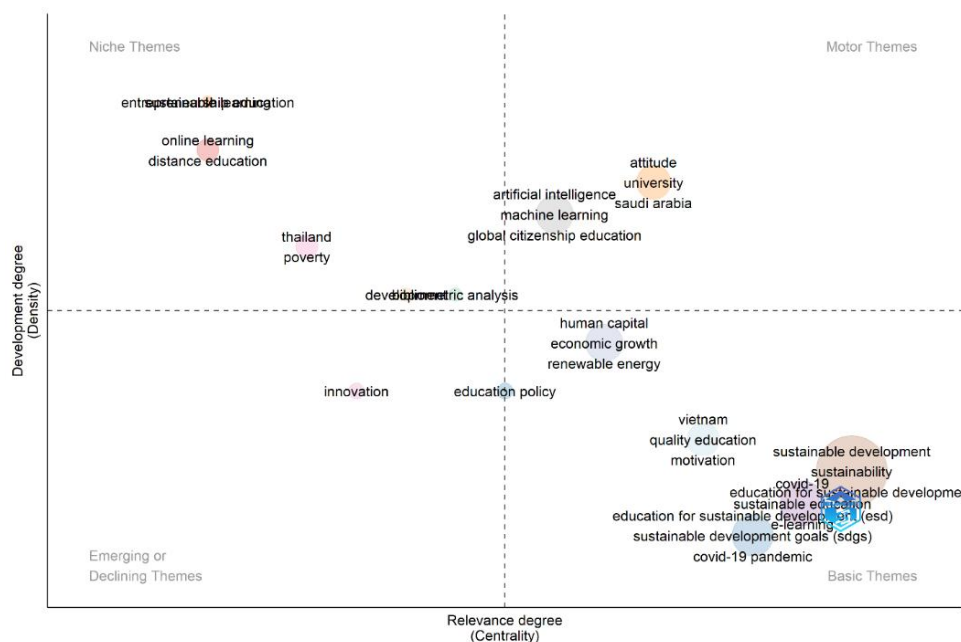


Figure 6. Thematic map of Education for Sustainable Development (ESD) research in Asian countries (2019–2023) based on Callon’s centrality–density framework.

A third cluster was associated with digital learning, online education, and artificial intelligence, indicating the growing prominence of technology-driven approaches. Additional clusters included themes related to economic development and human capital, as well as more specialized topics such as entrepreneurship education. The distribution of clusters suggests a field structured around a central sustainability core, with emerging thematic extensions in digital transformation and applied educational contexts.

Citation and Intellectual Structure

Citation analysis identified a small group of highly cited publications that exert a disproportionate influence on the field. The most cited articles accumulated more than 180 citations each, indicating the presence of a concentrated intellectual core.

Table 4a. Top five cited publications in ESD research in Global (2019–2023)

Rank	Author	Title	Journal	Citations	Impact
1	Voulvoulis (2022)	Systems thinking for sustainability transformation	Global Environmental Change	400+	Foundational work linking systems thinking with sustainability transformation; widely cited across interdisciplinary ESD research
2	Fekih Zguir (2021)	Embedding ESD and SDGs in curriculum	Journal of Cleaner Production	300+	Influential comparative study on curriculum integration of SDGs; strong policy and institutional relevance
3	Zeyer (2022)	Two-eyed seeing in ESD	Sustainability	250+	Conceptual contribution introducing holistic and integrative pedagogical approaches in ESD
4	Agbedahin (2019)	ESD and SDGs conceptual framework	Sustainable Development	240+	Seminal framework connecting ESD with SDGs; widely used as theoretical reference

Rank	Author	Title	Journal	Citations	Impact
5	Yang & Xiu (2023)	Bibliometric review of ESD	Sustainability	200+	Key bibliometric synthesis mapping global ESD research trends and knowledge structure

Table 4b. Top leading authors in ESD research in Asia (2019–2023)

Rank	Author	Country	Publications	Total Citations	h-index (local)	Role in Field
1	Li J	China	24	171	8	Leading contributor
2	Liu Y	China	20	209	8	High citation impact
3	Liu J	China	18	82	5	Active researcher
4	Zhang Y	China	18	132	6	Strong thematic contribution
5	Zhang X	China	17	79	5	Emerging influence
6	Li X	China	16	131	7	Consistent productivity
7	Wang J	China	16	130	5	Network collaborator
8	Wang Y	China	16	132	6	Balanced output and impact
9	Li Y	China	15	94	5	Moderate influence
10	Wang X	China	15	93	5	Emerging contributor

Co-citation analysis revealed six major clusters, representing the intellectual foundations of ESD research. Frequently co-cited works included foundational contributions in transformative learning, bibliometric methods, and policy transfer. These clusters reflect the interdisciplinary nature of the field, integrating perspectives from education, sustainability science, and research methodology. The structure of the co-citation network suggests that ESD research is anchored in a combination of pedagogical theory, sustainability frameworks, and methodological approaches.

Temporal Evolution of Themes

Temporal analysis revealed dynamic changes in thematic emphasis over the study period. Early-stage research (2019–2020) was dominated by themes related to curriculum and sustainability competencies. During the pandemic period (2020–2021), keywords such as online learning and COVID-19 emerged prominently, reflecting shifts in educational practice.

In the later period (2022–2023), digital transformation and artificial intelligence became increasingly prominent, indicating a shift toward technologically mediated sustainability education. At the same time, themes related to community engagement and policy integration began to gain visibility. These findings suggest a three-phase development pattern: initial consolidation, pandemic-driven transformation, and post-pandemic technological expansion.

Sensitivity analysis confirmed the stability of the results across variations in analytical parameters. Changes in keyword occurrence thresholds resulted in high levels of cluster consistency, while variations in counting methods produced only minor differences in network metrics. Excluding 2023 data did not substantially alter the main findings. These results indicate that the observed structural and thematic patterns are robust and not highly sensitive to parameter selection or temporal bias.

Discussion

This study examined the structural and thematic evolution of Education for Sustainable Development (ESD) research in Asia through a theory-informed bibliometric and network analysis. The findings reveal three interrelated patterns: a concentration of knowledge production, a fragmented yet partially connected collaboration structure, and a dynamic thematic evolution characterized by a stable sustainability core alongside emerging digital domains. These patterns are consistent with recent bibliometric scholarship, which emphasizes that research fields evolve through uneven growth, structural asymmetry, and thematic diversification rather than linear expansion.¹⁹

Structural concentration and knowledge production asymmetry

The concentration of research output within a limited number of countries and institutions indicates a structurally uneven knowledge production system. This finding aligns with recent ESD studies showing that publication output remains geographically concentrated in regions with stronger research infrastructure and policy support.²⁰ From the perspective of knowledge diffusion theory, this pattern suggests that the generation and circulation of knowledge are mediated by a small number of dominant actors, which function as central nodes within the scientific system. Such a configuration reflects a core-periphery structure, where central actors accumulate influence and visibility, while peripheral actors remain less integrated.

This structural asymmetry has important implications. While concentration may accelerate knowledge accumulation and standardization, it may also limit epistemic diversity and underrepresent locally grounded perspectives. These findings reinforce the argument that expanding ESD research requires not only increasing publication output but also improving inclusivity in knowledge production systems.

Fragmented collaboration and network dynamics

The collaboration network exhibits relatively low density and high modularity, indicating that research collaboration remains clustered rather than fully integrated. This pattern is consistent with scientific network theory, which suggests that localized clusters with limited cross-cluster interactions characterize fragmented networks.²¹ In such systems, knowledge diffusion is often mediated by a small number of highly central actors who act as brokers connecting otherwise disconnected groups.²²

This interpretation is further supported by the policy transfer literature, which emphasizes that knowledge circulation in global systems is neither uniform nor automatic

¹⁹ Donthu et al., "How to Conduct a Bibliometric Analysis: An Overview and Guidelines"; Öztürk, Kocaman, and Kanbach, "How to Design Bibliometric Research: An Overview and a Framework Proposal."

²⁰ Shih Chieh Chien and Charles Knoble, "Research of Education for Sustainable Development: Understanding New Emerging Trends and Issues after SDG 4," *Journal of Sustainability Research* 6, no. 1 (2024), <https://doi.org/10.20900/jsr20240006>.

²¹ van Eck and Waltman, "Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping."

²² Donthu et al., "How to Conduct a Bibliometric Analysis: An Overview and Guidelines."

but is mediated by specific actors and institutional networks.²³ In the context of ESD research, this implies that regional knowledge exchange depends heavily on key countries and institutions that facilitate cross-national collaboration.

The persistence of fragmented structures suggests that ESD research in Asia is still in a transitional stage of network development. Although collaboration has expanded, it has not yet reached a level of systemic integration that would enable fully distributed knowledge exchange. Strengthening cross-cluster collaboration, therefore, remains a critical challenge for advancing the field.

Thematic evolution and the rise of digitally mediated ESD

The thematic structure of the field reveals a stable core centered on sustainability discourse, particularly themes related to SDGs and higher education. This reflects the strong influence of global sustainability agendas in shaping research priorities. At the same time, the emergence of digital learning, artificial intelligence, and technology-enhanced education indicates a significant shift toward technologically mediated ESD.

This shift is consistent with recent studies showing that the post-pandemic period has accelerated the integration of digital technologies into sustainability education.²⁴ Furthermore, emerging research highlights the growing role of generative artificial intelligence in supporting SDG 4, particularly in expanding access to education and enabling new pedagogical approaches.²⁵

However, this transition also raises important conceptual questions. While digital technologies enhance scalability and accessibility, their alignment with the transformative goals of ESD—such as critical thinking, value formation, and systemic awareness—remains uncertain. The findings, therefore, suggest that the field is entering a phase of conceptual reconfiguration, in which the integration of technology must be carefully aligned with the foundational principles of sustainability education.

Policy influences and global agenda alignment

The prominence of SDG-related themes underscores the role of global policy frameworks in shaping research agendas. From a policy transfer perspective, this reflects the diffusion of international policy narratives into academic research, influencing both thematic priorities and research direction²⁶. Rather than emerging independently, ESD research is closely aligned with globally endorsed sustainability goals.

At the same time, the interaction between global policy frameworks and regional research systems is not uniform. While global agendas provide a shared reference point,

²³ Diane Stone, Osmany Porto de Oliveira, and Leslie A Pal, "Transnational Policy Transfer: The Circulation of Ideas, Power and Development Models," *Policy and Society* 39, no. 1 (January 2, 2020): 1–18, <https://doi.org/10.1080/14494035.2019.1619325>.

²⁴ Chien and Knoble, "Research of Education for Sustainable Development: Understanding New Emerging Trends and Issues after SDG 4."

²⁵ Prema Nedungadi, Kai-Yu Tang, and Raghu Raman, "The Transformative Power of Generative Artificial Intelligence for Achieving the Sustainable Development Goal of Quality Education," *Sustainability* 16, no. 22 (November 9, 2024): 9779, <https://doi.org/10.3390/su16229779>.

²⁶ Stone, Porto de Oliveira, and Pal, "Transnational Policy Transfer: The Circulation of Ideas, Power and Development Models."

their implementation varies across local research capacities and institutional conditions. This highlights the importance of understanding ESD research as a product of both global policy alignment and regional structural dynamics.

Toward a systemic understanding of ESD knowledge ecosystems

The integration of structural, network, and thematic findings suggests that ESD research can be conceptualized as a dynamic knowledge ecosystem shaped by the interaction of policy frameworks, collaboration networks, and thematic evolution. This perspective aligns with recent bibliometric research emphasizing the need to move beyond descriptive mapping toward systemic explanations of knowledge production.²⁷

Within this ecosystem, policy frameworks such as the SDGs shape research priorities, collaboration networks mediate knowledge diffusion, and thematic structures reflect the evolving intellectual landscape. These elements interact recursively, with emerging themes—such as digital transformation—influencing future research agendas and policy directions. This highlights the co-evolutionary nature of sustainability-oriented research.

Implications for research and practice

The findings have several implications. Theoretically, this study demonstrates the value of integrating bibliometric analysis with network theory and policy frameworks to explain the evolution of research fields. This approach contributes to a more comprehensive understanding of ESD as a complex and dynamic knowledge system.

Practically, the results suggest the need for policy interventions to enhance collaboration and inclusivity in ESD research. Promoting cross-national partnerships, particularly involving underrepresented countries, may help reduce structural fragmentation and improve knowledge diffusion. In addition, the growing prominence of digital themes underscores the importance of aligning technological innovation with the transformative goals of sustainability education.²⁸

This study is subject to several limitations. The analysis is restricted to English-language publications indexed in Scopus, potentially underrepresenting regional scholarship. Citation-based indicators are also affected by time-lag effects, particularly for recent publications. In addition, bibliometric results are sensitive to methodological choices, including data cleaning procedures and threshold selection.²⁹ These limitations should be considered when interpreting the findings.

CONCLUSION

This study provides a comprehensive examination of the structural and thematic evolution of Education for Sustainable Development (ESD) research in Asia using a bibliometric and network-based approach. The findings reveal that, although the field has

²⁷ Öztürk, Kocaman, and Kanbach, “How to Design Bibliometric Research: An Overview and a Framework Proposal.”

²⁸ Natasha Pennell and Gabriela Sabau, “The Impact of Multidisciplinary Program Requirements on Student Attitudes toward Sustainability and Education for Sustainability,” *International Journal of Sustainability in Higher Education* 25, no. 3 (February 19, 2024): 669–87, <https://doi.org/10.1108/IJSHE-06-2022-0199>.

²⁹ Lim, Kumar, and Donthu, “How to Combine and Clean Bibliometric Data and Use Bibliometric Tools Synergistically: Guidelines Using Metaverse Research.”

experienced substantial growth between 2019 and 2023, this expansion is characterized by structural concentration, fragmented collaboration networks, and dynamic thematic shifts. Knowledge production remains concentrated in a limited number of countries and institutions, indicating persistent asymmetries in research capacity and influence. At the same time, collaboration patterns exhibit moderate connectivity and high modularity, suggesting that the regional research network is only partially integrated and remains organized around clustered subnetworks. Thematically, ESD research is anchored in a stable sustainability core while increasingly incorporating digital technologies, reflecting a transition toward technologically mediated sustainability education. These findings indicate that the development of ESD research in Asia is best understood as a systemic process shaped by the interaction of policy frameworks, knowledge diffusion, and thematic innovation rather than as a linear expansion of scholarly output.

This study contributes to the literature by offering a region-specific and theory-informed analysis that integrates bibliometric performance, network structure, and thematic evolution. It highlights the need to move beyond descriptive mapping toward a more explanatory understanding of how sustainability-oriented research fields develop. From a practical perspective, the findings suggest the importance of strengthening cross-national collaboration to reduce structural fragmentation and enhance knowledge diffusion across the region. Additionally, the growing prominence of digital themes underscores the need to align technological innovation with the transformative goals of sustainability education. Despite these contributions, the study is limited by its reliance on English-language publications indexed in Scopus and by the inherent constraints of citation-based indicators. Future research should expand database coverage, incorporate longitudinal and comparative designs, and integrate qualitative approaches to capture better the relationships among research development, policy implementation, and educational practice.

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