Frontier Hot Topics and Evolutionary Paths in Ecological Civilization Education Research —Analysis Based on the LDA Topic Model

Wenqian Lyu Yunhua Liu

Abstract： As a core pathway for advancing sustainable development, ecological civilization education has increasingly become a focal point in international scholarship and educational practice. To systematically identify trends in the evolution of research themes, this study draws on the Web of Science Core Collection. It applies a Latent Dirichlet Allocation (LDA) topic model to analyze English-language journal articles on ecological civilization education published between 2011 and 2024. The findings indicate, first, that international research on ecological civilization education has shown a trend toward thematic expansion in response to evolving events and emerging issues. Second, this evolution displays a structural pattern of a stable internal core alongside an expanding external periphery, reflecting a developmental trajectory in which foundational themes gradually extend from practice-oriented layers to more diversified integration. Third, recent research hotspots have concentrated on five directions: climate change, food waste and sustainable consumption, biodiversity, community participation, and green development. Although substantial scholarly exploration has been undertaken across these five themes, the field as a whole continues to face challenges, including fragmented curricula, disciplinary silos, a gap between knowledge and action, underdeveloped mechanisms, and a limited cultural lens. Future progress, therefore, requires coordinated reforms across policy, institutional arrangements, and teaching practice.

Key Words： sustainable development; LDA topic model; ecological civilization education; bibliometric analysis

Since the adoption of Agenda 21: Programme of Action for Sustainable Development by the United Nations in 1992, global efforts toward sustainable development have continued to advance, and ecological civilization education—aimed at promoting harmonious coexistence between humans and nature—has gradually become a focal point of international academic and practical attention. As countries increasingly emphasize environmental protection and sustainable development, scholars have conducted in-depth research on their core concepts, influencing factors, and practical pathways. International journal publications on ecological civilization

education serve as an important medium for disseminating research outcomes in this field. Identifying research hotspots and evolutionary trajectories, as well as analyzing and forecasting future trends, not only contributes to a comprehensive understanding of the current research landscape but also provides valuable references for ecological civilization education research in China and globally.

I. Problem Statement

The report of the 18th National Congress of the Communist Party of China emphasized that "greater conscious effort must be made to treat comprehensive, coordinated, and sustainable development as a fundamental requirement for thoroughly implementing the Scientific Outlook on Development," and incorporated the construction of ecological civilization into the national strategy for future development[1]. This statement clearly delineates the responsibilities that education should assume in advancing ecological civilization. As a form of foundational quality-oriented education, ecological civilization education not only helps enhance public understanding of ecological civilization, foster a scientific ecological worldview, cultivate innovative capacity, and develop ecological character, but also contributes to the promotion of social equity[2]. In recent years, bibliometric methods have been widely applied in research on ecological civilization education and have become an important tool for examining the field's current landscape and future trends. By quantitatively analyzing large-scale bibliographic data, these methods can reveal research hotspots, scholarly collaboration networks, and frontier developments in ecological civilization education. For example, Chen Shijian and colleagues used CiteSpace to conduct collaboration network analysis and to map knowledge structures in domestic and international research on ecological civilization education[3]； Ren Shuai and others likewise employed CiteSpace to visualize hotspots and trends in green education research[4]. Traditional topic analysis approaches, such as co-citation analysis and burst-term detection, can extract thematic structures and research frontiers; however, they face limitations when handling large-scale datasets[5].

Latent Dirichlet Allocation (LDA), an unsupervised learning algorithm, can automatically identify latent topics in a corpus without manual annotation. In recent years, researchers have attempted to incorporate temporal dimensions into LDA-based analyses. For instance, Zhu Guang

and colleagues examined topic time spans based on life-cycle theory[6]; Liu Yashu applied LDA to online public-opinion data, classified topics, and traced their evolution using multidimensional features such as entity attributes and temporal attributes[7]. Moreover, integrating LDA with time-series analysis enables more rigorous modeling and forecasting of development trends in ecological civilization education, providing more objective and precise informational support for related research. Against this backdrop, the present study employs an LDA topic model to conduct text-based modeling and analysis of English-language journal articles in the Web of Science Core Collection whose titles contain "ecological civilization education," "environmental education," and "education for sustainable development." The optimal number of topics is determined by calculating perplexity, thereby ensuring the scientific validity and rationality of topic extraction. After in-depth analysis of the resulting document–topic matrix and topic–word matrix, the study identifies core research themes in the field. Based on LDA outputs, it further computes topic strength across successive time windows, visualizes topic intensity using a heat map, and determines evolutionary relationships among topics by calculating cosine distances between topics and their keywords across adjacent time windows. Finally, by combining indicators of topic intensity and novelty, the study identifies research hotspots and, in a relatively objective and systematic manner, reveals the frontier directions and evolutionary pathways of international research on ecological civilization education—providing data support and theoretical reference for future theoretical development and practical innovation in this area.

II. Research Design

To examine international research hotspots in ecological literacy education and their evolutionary patterns, this study applies LDA topic modeling and topic vector space modeling. Combined with life-cycle theory, it systematically maps the dynamic pathways through which research hotspots emerge, develop, and shift over time.

(1) Research Framework

To systematically investigate the evolutionary trajectory of research hotspots in international ecological literacy education, this study constructs a bibliographic dataset from the Web of Science Core Collection. It uses article abstracts as the primary analytical corpus. By adopting a dynamic time-window strategy, the study analyzes different temporal segments to identify

clustering characteristics of research topics at each stage, ultimately visualizing changes in topic intensity and the evolution pathways within ecological civilization education research.

First, during the text-mining stage, the study employs the Latent Dirichlet Allocation (LDA) topic model to identify topics from large-scale unstructured corpora. Built on a three-layer Bayesian generative structure, the model represents each article as a mixture of multiple latent topics. Here, $P(z/d)$ denotes the document–topic distribution, and $P(W/z)$ denotes the topic–word distribution. Using a variational EM algorithm, the hyperparameters α and β *are* optimized, and the optimal number of topics K, is determined according to the minimum-perplexity criterion. This procedure helps ensure both the distinctiveness and representativeness of the extracted topics, thereby enabling the effective identification of the major thematic structure of research on ecological civilization education[8].

$$p(w|d)=\sum_{z} p(w|z)\cdot p(z|d)$$

Second, to analyze the temporal evolution pathways of research themes, this study further introduces a vector-space modeling approach. Specifically, the topic–word probability distributions generated by the LDA model within each time window are vectorized to form a matrix of topic-feature vectors. The cosine similarity between topic feature vectors in adjacent time windows is then calculated to quantify the degree of similarity between topics across successive periods[9]. In the topic-evolution analysis stage, a three-step procedure(temporal slicing, topic vector modeling, and similarity computation) is integrated to construct a topic evolution map. More specifically, the whole observation period is divided into a set of dynamic time windows $T=\{t_1,\ldots,t_n\}$, and a corpus sequence is constructed with temporal continuity. Next, for each time window, feature vectors are generated for the extracted topics, and cosine similarity is computed between topics in adjacent time windows to identify evolutionary relationships across time. In this study, a topic is considered to exhibit continuity when the similarity value satisfies Sim ≥ 0.65[10].

$$\mathrm{Sim}(z_{t_i},z_{t_j})=\frac{\vec{v}_{z_{t_i}}\cdot\vec{v}_{z_{t_j}}}{\left\|\vec{v}_{z_{t_i}}\right\|\cdot\left\|\vec{v}_{z_{t_j}}\right\|}$$

Third, in identifying research hotspots, this study introduces life-cycle theory and analyzes the evolutionary trends of hotspots by integrating topic occurrence frequency with their positions

in the time series. Specifically, the hotness indicator (Hotness, HT) measures the level of attention a given topic receives over a specified period[11]. In addition, a novelty index (Novelty Index, NI) is defined to assess the relative recency of a topic's emergence. Using the mean value of topic novelty as the classification threshold, all topics are categorized according to the combined features of hotness and novelty into: "hot topics" (high hotness, low novelty), "frontier topics" (high hotness, high novelty), and "peripheral topics" (low hotness, high novelty)[12].

$$HT_z^{t_i} = \frac{N_z^{t_i}}{N_{\text{total}}^{t_i}} \times 100\%$$

(2) Data Sources

This study uses the Web of Science Core Collection as its primary data source. The search field was set to "SU" (research subject), and the search query was: SU = "ecological civilization education" OR "environmental education" OR "sustainable development education". The time span was limited to 2011–2024, and the final search time was on 29 December 2024. The author retained 40,743 English-language documents after removing duplicates and excluding records with incomplete information. All abstracts were extracted as the raw corpus for text modeling and served as the primary data source for analysis, and the dataset was then organized by year of publication.

As shown in Figure 1, the number of publications was relatively low and sporadic from 2011 to 2018. From 2019 onward, although annual figures fluctuated slightly, the overall trend has been steady. To balance sample sizes across periods, the literature on international ecological civilization education was divided into three time periods: 2011–2018, 2019–2022, and 2022–2024. Subsequently, using article abstracts as the corpus for the LDA model, the study employed Python's Natural Language Toolkit (NLTK) for preprocessing, including tokenization and lemmatization, to improve modeling accuracy. Finally, the processed text feature vectors were fed into the LDA model for subsequent topic identification and analysis.

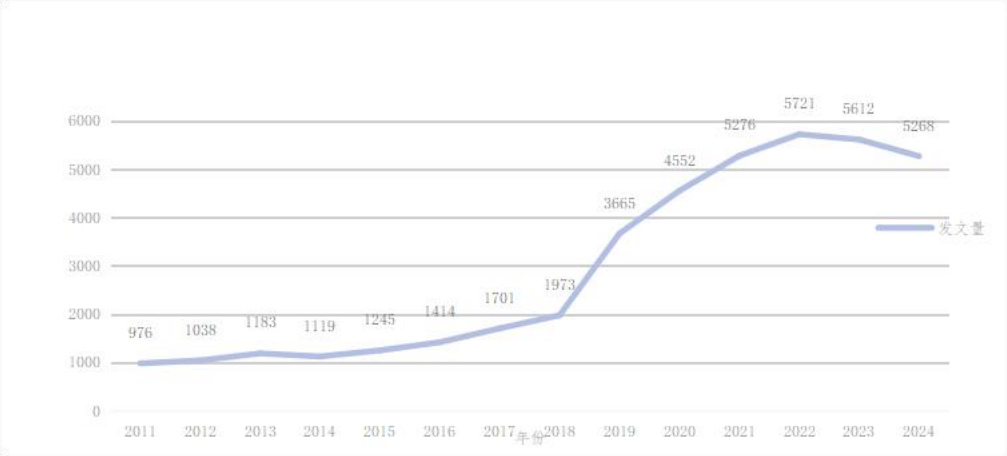

Figure 1: Publication Trends in International Research on Ecological Civilization Education

III. Results and Analysis

To trace the developmental trajectory of international research on ecological civilization education, this study conducts a systematic analysis using the LDA topic model. First, it identifies research themes across different periods and constructs a topic–vocabulary system. Second, topic heat maps reveal the level of attention and the dynamic changes in each theme over time. Finally, Sankey diagrams are employed to illustrate the inheritance and transformation of research hotspots, thereby presenting the evolutionary pathways of this research field.

(1) Topic Extraction

In LDA-based analyses of ecological civilization education, the perplexity metric can optimize and determine the number of topics. Specifically, cross-validation is conducted separately for corpora from different time periods, and the topic number K corresponding to either the minimum value of the perplexity curve or a pronounced elbow point is selected as the optimal parameter. The final results indicate that the optimal number of topics is 23 for the 2011–2018 period, 22 for 2019–2021, and 34 for 2022–2024.

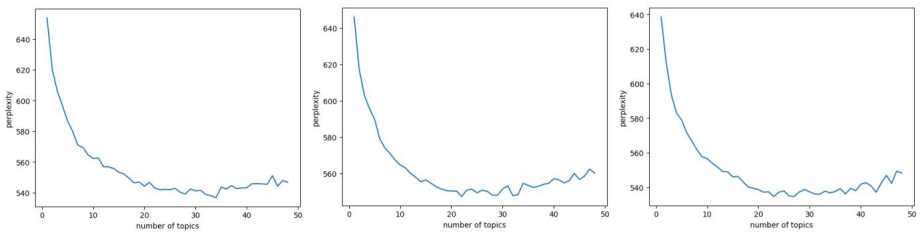

Figure 2. Topic Perplexity across Different Time Windows

Subsequently, using the Gibbs sampling algorithm to train the LDA model, with both corpus size and computational efficiency taken into account, and, based on pilot testing, setting the number of iterations to 150 to ensure stable model convergence. During the topic post-processing stage, words that fall below a predefined topic-relevance threshold and those lacking sufficient bibliographic support are removed. The remaining topics were then semantically labeled using the Web of Science subject classification system to ensure semantic accuracy, disciplinary consistency, and clear differentiation among topics.

Time Window	Optimal Number of Topics	Final Number of Topics	Topic Labels
2011-2018	23	12	Climate Change、Sustainable Development、Environmental Research、Teacher Literacy、Student Learning 、Knowledge Behavior Perception、Childhood Health、 Food Consumption、Social Participation、Conservation Biodiversity、Energy Efficiency、Water、 Social Wellbeing and Support、Urban
2019-2021	22	13	Sustainable Higher Education、Sustainable Development、Water、School Teaching Curriculum、Ecological Conservation Tourism、 Community Resilience Participation、 Climate Change、Children's Activity、Green Energy Consumption、Childhood Health、Student Learning 、Knowledge Behavior Perception、 Social Well-being and Support、Urban Ecological
2022-2024	34	22	Community Participation、Professional Educational Development、 Natural Resources、Conservation Awareness、 University Student Performance、Digital Technology Research Teacher Literacy、Childhood Health、Pandemic Activity、Green Innovation in Business、Social Wellbeing and Support、Sustainable Development、Online Learning Experiences、Sustainable Higher Education、Water、Waste Management、Science Curriculum、Energy Efficiency、Sustainable Food Consumption、Climate Change Adaptation、Urban Ecological

Table 1. Topic Distribution across Different Time Windows in International Research on Ecological Civilization Education

(2) Topic Hotness

The heat map illustrates changes in research themes in international ecological civilization education across three time windows (2011–2018, 2019–2021, and 2022–2024). The color intensity represents the level of topic attention in the corresponding period: darker colors indicate higher research hotness, while lighter colors suggest relatively lower attention. This visualization provides an intuitive representation of the dynamic evolution of research priorities and offers graphical support for understanding scholarly trends in ecological civilization education.

From a temporal perspective, research themes during 2011–2018 were relatively limited, concentrating mainly on climate change, sustainable development, and students' learning, cognition, and behavioral patterns. Between 2019 and 2021, the thematic scope expanded, with

growing attention to sustainable development in higher education, urban ecological protection, and science education. In 2022–2024, the number of themes increased markedly and expanded into emerging areas, including digital technologies, green innovation, online learning, and eco-citizenship. This pattern indicates a continuing expansion of the research landscape and a deeper integration with broader social development agendas.

From a content perspective, early studies primarily examined the relationships among ecological civilization education and schooling, health promotion, and social well-being, emphasizing individuals' cognitive, behavioral, and participatory mechanisms. Over time, the research focus broadened to encompass broader societal domains, including sustainability in higher education, community engagement, and water resource management. In recent years, attention has further shifted toward the application of digital technologies, innovation and entrepreneurship education, green energy development, and online learning models. This shift suggests that ecological civilization education is increasingly intersecting with modern technology, economic development, and policy orientations, reflecting an increasingly integrated, practice-oriented evolutionary trajectory.

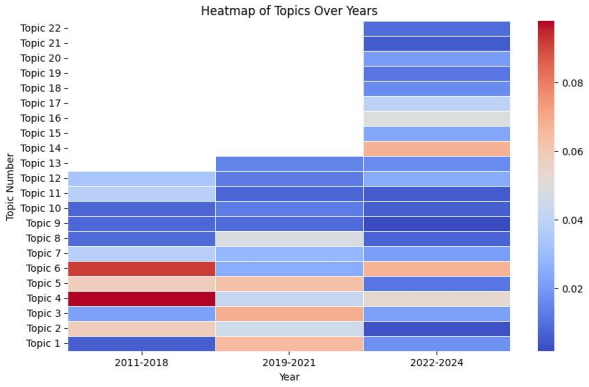

Figure 2 Topic Hotness Heat Map for International Research

(3) Topic Evolution

Sankey diagrams are well-suited for analyzing the evolutionary pathways of research themes and their relationships. To ensure that the topic evolution paths presented in the diagram are semantically plausible, this study first constructs a corpus sequence with temporal continuity. It then extracts topic feature vectors for each time window and conducts topic matching and comparison across adjacent time windows. When the similarity between two topics is greater than

or equal to 0.65, a continuity relationship is assumed[①]. On the one hand, the arrangement of blocks across time windows enables identification of topics that remain continuous or disappear; on the other hand, the direction and strength of inter-topic flows reveal shifts in research priorities and broader evolutionary trends.

From a temporal perspective, research on ecological civilization education generally follows an evolutionary trajectory from foundational issues to broader integration, and then toward diversified convergence. In the early stage, research hotspots focused on issues related to quality of life and fundamental ecological conditions, such as social well-being, water resource management, food waste, and children's health. As research deepened, attention gradually expanded to include sustainability in higher education, student learning, community participation, and science education, indicating a shift in the research center of gravity from ecological conditions per se to educational practice and public engagement. In the later stage, particularly from 2022 onward, the research agenda shows a marked trend toward diversification and cross-domain integration, with emerging topics such as digital technologies, online learning, green innovation, eco-citizenship, and entrepreneurial behavior.

"Internal evolution" refers to the dynamic linkages and transitions among established themes within ecological civilization education research. Analyzing these internal evolutionary relationships helps reveal the high level of interaction and interdependence among issues within the field. At present, internal topic evolution in ecological civilization education exhibits strong systematization and pronounced multidimensional expansion, as reflected in the following five aspects. First, a relatively stable, tightly connected knowledge network has formed around themes such as social well-being, learning behavior, and sustainable development, constituting the core research framework for ecological civilization education. Second, internal evolutionary dynamics have driven an expansion of research attention from educational settings toward disciplinary teaching, and from learning processes toward competence construction. For instance, the evolution from "schools" to "science education" suggests that the research focus has shifted from educational space to subject-specific pedagogy, highlighting the central role of scientific literacy

① In the diagram, the blocks represent research topics in different time windows, and the size of each block reflects the topic's hotness in the corresponding period, that is, the number of related publications. The lines connecting blocks indicate topic flows across time windows: the wider the line, the stronger the continuity of the topic between adjacent windows and the greater the inheritance of research attention.

in ecological education. Third, traditional themes continue to generate scholarly momentum in response to emerging topics, producing an evolutionary pattern of "stable core and expanding periphery." Topics such as sustainable development and climate change not only show strong continuity but also exhibit close connections with emerging issues, reflecting increasing thematic complexity. Fourth, specific topics play clear bridging roles. For example, "sustainability in higher education" both inherits evolutionary pathways from traditional themes such as social well-being and support, as well as from knowledge–behavior–cognition. It extends into emerging domains such as science education and digital technologies, indicating its position as an intermediary node within the research network, linking conventional concerns with frontier agendas. Fifth, research objects and content have gradually become more fine-grained, suggesting that ecological civilization education has moved from a stage of conceptual dissemination to a phase of deepening practice. Concretely, research has evolved from broad "ecological awareness" toward more differentiated dimensions such as learning literacy, behavioral cognition, physical activity, and food consumption.

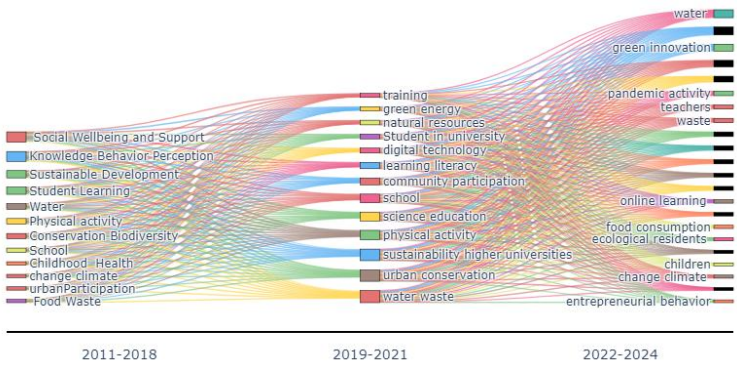

Figure 3 Topic Evolution Map of International Research on Ecological Civilization Education

While continuing to deepen its core themes, research on ecological civilization education also demonstrates a pronounced pattern of "external evolution," namely, the continual introduction of new domains and perspectives. As indicated by the topic evolution map, the field is currently undergoing three major trends: first, a shift from macro-level concepts to concrete practice; second, an expansion from traditional educational paradigms toward technology-driven and lifelong learning models; and third, a move from single-discipline approaches toward multidisciplinary integration. Among these trends, the deep integration between ecological civilization education and digital technologies is particularly salient. Across multiple themes—such as science education,

sustainability in higher education, and student learning—elements of digital technology have been incorporated, suggesting that the instrumental and transformative functions of technology in ecological education are becoming increasingly prominent. In addition, the research agenda is expanding along multiple dimensions, mainly in four respects. First, research attention has gradually extended from macro-level issues to environmental governance practices. The emergence of themes such as waste management and resource utilization indicates that scholarship is beginning to address operational aspects of environmental protection, emphasizing practical content including energy conservation and emissions reduction, pollution control, and recycling and circular use. Second, educational actors and pedagogical approaches are diversifying. Growing attention to issues such as digital transformation, lifelong learning, and the responsibilities of higher education reflects an expansion of ecological education beyond school-based instruction toward cross-age and cross-media forms of learning. Third, ecological civilization education is becoming more closely intertwined with the green economy and social innovation. The emergence of the theme of green innovation suggests that the field is moving beyond the boundaries of education as an internal domain into interdisciplinary intersections with green entrepreneurship, ecological economic development, and social sustainability. Fourth, climate change remains a significant topic of sustained attention, yet its role in the literature is shifting. Current studies increasingly treat climate change as a target of educational intervention rather than merely a source of environmental problems, indicating a transition in research emphasis from problem recognition toward policy response and integrated governance.

（4）Topics Frontiers

Hotspot identification is an approach for mining and analyzing high-impact themes within a specific research field. It typically integrates techniques such as text mining, machine learning, and network analysis to process large-scale bibliographic data and identify topics that exhibit high research attention, rapid growth, or frontier characteristics within a given period. Based on the topic distribution of the retrieved literature, this study calculates the hotness and novelty of each topic[①]. Then, the mean novelty value across all topics is used as the threshold, following the

① Hotness is used to measure the level of attention a topic receives in the research landscape; it is calculated as the proportion of publications associated with that topic relative to the total number of publications in the same period. Novelty reflects the temporal attribute of topic emergence and is defined in terms of the relationship between the year in which the topic first appeared and the current analytical time point.

method proposed by Zhou Jian et al. Topics with relatively high hotness but low novelty are classified as "hot topics" [13] In addition, a "two-dimensional topic scaling" approach is adopted, in which topics are classified along two dimensions—hotness and novelty, to identify and differentiate topic types. Ultimately, five hot topics are identified within international research on ecological civilization education.

	Topic1	Topic2	Topic3	Topic4	Topic5
hot topics	change	food	conservation	community	development
Top words	climate	waste	species	local	economic
	green	consumption	ecological	communities	growth
	changes	products	local natural	program	china
	adaptation	recycling	nature	participation	financial
	impacts	consumers	tourism	project	impact
	global	nutrition	biodiversity	research	effect

Table 2 Topics Frontiers of Ecological Civilization Education

a. Climate Change

Climate change is one of the most urgent environmental challenges of our time and a core issue in ecological civilization education. Climate change education aims to promote transformative shifts toward sustainable development by enhancing the public's awareness of the climate crisis and strengthening their capacity to respond. At present, the international community has widely recognized the pivotal role of education in addressing climate change. The United Nations Framework Convention on Climate Change calls on countries to raise public climate awareness and adaptive capacity through education[13]. Driven by growing policy consensus, scholarly research on the role of education in climate action has deepened. Viewed from current trends, the literature on climate change education can be broadly grouped into three main areas of emphasis.

First, research concentrates on how climate change content can be embedded across educational levels, from scientific understanding of climate change to adaptation and mitigation strategies, while positioning young people as agents of change and emphasizing the development

of both a global perspective and local adaptive capacity[14]. In this background, interdisciplinary teaching has become a dominant practice-oriented approach. Many studies highlight experiential learning and encourage students to translate knowledge into action through activities such as calculating ecological footprints, conducting energy-saving experiments, engaging in role play, participating in public debates, and taking part in local greening initiatives[15][16][17].

Second, the advancement of climate education faces challenges on multiple fronts, spanning both macro-level policy constraints and micro-level classroom practice. On the one hand, policymakers often underestimate the importance of climate education. In many countries, climate issues are not adequately incorporated into curricula when they are designed or revised. A 2021 survey by UNESCO also reported that, among 100 countries, 47% of national curriculum documents did not mention "climate change"[18]. On the other hand, a gap persists between scientific knowledge production and educational practice[19]. One set of challenges relates to structural issues within the knowledge transmission process itself. Scientific content is not always communicated with sufficient precision, nor is it updated promptly, which can lead students to confuse key terms, principles, and concepts such as "global warming" and the "ozone hole"[20]. In classroom practice, interdisciplinary integration also remains limited: climate issues are still largely confined to natural science subjects, with insufficient input from the social sciences[21]. Moreover, educational considerations receive relatively little attention in major systematic assessment reports on global climate change issued by *the Intergovernmental Panel on Climate Change* (IPCC). A second challenge concerns the imbalance of curricular content selection. Different countries often display strong preferences for what they include, leading to divergent instructional emphases. As a result, some teaching practices focus primarily on individual behavioral choices while underestimating the importance of structural factors such as policy frameworks and collective action[22]. Other curricula, by contrast, are dominated by crisis-oriented "grand narratives," which may generate anxiety and helplessness among students and provide insufficient guidance toward feasible pathways for positive action[23].

Third, to address these issues, climate change education needs to be more systematically integrated into both policy and practice, including incorporation into national curricula and teacher professional development. At the same time, innovative pedagogical approaches should be

developed to narrow the gap between knowledge and action and to strengthen the public's capacity for climate action.

b. Food Waste and Sustainable Consumption

According to a United Nations Environment Programme report, approximately 17% of food at the consumer level, around 931 million tonnes, was directly discarded in 2019, indicating that food waste and unsustainable consumption remain severe on a global scale[24]. Against this backdrop, food waste and sustainable consumption have increasingly become another major hotspot in ecological civilization education research. The aim is to reduce food waste and promote frugal and sustainable consumption habits through education, thereby alleviating resource pressures and environmental impacts. Existing studies mainly examine how to cultivate sustainable consumption values among the public and adolescents, and how to embed the concept of green consumption into everyday contexts such as school cafeterias and household kitchens.

On the one hand, existing studies highlight several dilemmas in educational practices themed around food waste and sustainable consumption. First, curricular content is often fragmented and fails to cover the full consumption cycle. For example, research suggests that sustainability-oriented curricula rarely address the entire process from production and distribution to consumption and disposal, which means that students may not learn effective strategies for reducing waste at the source[25][26]. Second, there is a disconnect between educational theory and practice. Young people frequently exhibit a pronounced "intention–action" gap in sustainable consumption: they may prioritize sustainability goals before making purchases, yet overlook or forget them during actual consumption.[27]. As a result, if practical programs lack robust evaluation and follow-up mechanisms, students may acquire knowledge about food waste and sustainable consumption in class without translating it into meaningful and sustained behavioral change[28].

On the other hand, a substantial body of research proposes two main strategies for strengthening educational practice. First, the concepts of food waste reduction and sustainable consumption should be systematically embedded across all levels of education. This may include integrating content on waste reduction and circular use into curriculum standards so that students develop habits of frugality from an early age; combining health and nutrition education with sustainable consumption by offering age-appropriate modules on balanced diets in primary

schools to promote both healthy eating and environmental awareness; emphasizing preventive approaches[29]; and cultivating students' "food waste literacy Second, learning depth should be enhanced through cross-actor collaborative mechanisms. Schools, communities, and government agencies can jointly support experiential learning projects, such as school gardening, household food-waste reduction challenges, and similar initiatives, so that the public can strengthen awareness and skills through practice. These efforts can be complemented by institutional tools, such as green points systems and campus carbon accounts, that enable students to complete the transition from knowledge to action across diverse settings. In addition, educational interventions should move beyond a narrow focus on "individual lifestyle change" toward reforms at the institutional and cultural levels.[30].

c. Biodiversity Conservation

Global biodiversity is facing severe challenges, with an estimated one million plant and animal species threatened with extinction[31].This crisis calls for a clear response and active engagement from education systems. As a United Nations report has noted, education for sustainable development should equip people with the knowledge and skills needed to address environmental challenges such as biodiversity loss[32].As one of the key hotspots in ecological civilization education, biodiversity and ecological conservation center on promoting respect for, and protection of, nature within education, while enhancing public understanding of species diversity and the value of ecosystems.

First, at the level of educational objectives, research addressing the question "What knowledge and competencies should biodiversity education cultivate?" offers valuable guidance. For example, Solovjeva et al., adopting an ecosystem services perspective, argue that biodiversity education should encompass environmental protection, human well-being, cultural diversity, and sustainable development[33]. Klemow et al. propose a four-dimensional ecological framework, emphasizing that biodiversity education should integrate ecology, ethics, and cultural studies to guide students in understanding species diversity from multiple disciplinary perspectives[34]. In terms of teaching practice, biodiversity education emphasizes experiential learning, interdisciplinary instruction, and place-based learning to strengthen young people's connection to nature and cultivate environmental responsibility. First, experiential learning is commonly implemented through outdoor instruction, direct nature experiences, and community science

outreach. Second, interdisciplinary approaches tend to incorporate multiple disciplines or emerging technologies—for instance, using food-chain simulations to illustrate ecological relationships, or drawing on Indigenous stories to examine the relationship between humans and nature[35]. Third, place-based learning is grounded in local resources and contexts, such as visiting nature reserves, documenting urban ecological micro-environments, managing school gardens, or caring for small animals[36][37].

Meanwhile, alongside practical exploration, many studies also point to the real-world challenges of implementing biodiversity education. On the one hand, teaching practice often suffers from a spatial disconnect. When students participate in local investigations, they may find it challenging to link these experiences to the global problem of species extinction, which in turn constrains their understanding of the issue as an integrated whole[]. For students living in urban environments, limited day-to-day contact with nature may also generate a sense of "nature disconnection," reducing their willingness to translate learning into action. On the other hand, curricular depth is frequently insufficient, and key concepts such as genetic diversity and ecosystem functioning are often neglected in classroom instruction[38].

In response, the literature proposes several actionable pathways for improvement. Specifically, building on interdisciplinary teaching, schools can establish a tripartite collaboration mechanism linking schools, communities, and conservation institutions to provide students with opportunities to participate in authentic conservation efforts[39]. Curriculum design should also place greater emphasis on thematic modules and activities centered on ecosystem services and species protection, enabling students to develop a systematic understanding of the relationships between biodiversity and human society, cultivate an identity as ecological stewards, and engage more deeply in conservation practice.

d. Community Participation

Community-based education emphasizes mobilizing public engagement in environmental action at the local level. Existing research indicates that environmental education programs implemented through community platforms can enhance community members' capacity to respond to environmental challenges[40]. Current studies are primarily organized around the principle of "learning from the community," and examine this area from multiple angles, including the current situation, existing problems, and potential strategies.

First, practice-oriented studies in this area mainly focus on two strands: the adoption of international experience and the exploration of locally grounded models. In terms of international experience, some countries in the United States and Europe have developed a tripartite collaboration model linking schools, communities, and the environment. By engaging students directly in real-world projects such as urban governance and ecosystem services, these initiatives enhance students' ecological citizenship and action capacity[41][42].Related curriculum frameworks in South Korea and the Netherlands emphasize the integration of service learning with project-based practice, cultivating students' sense of responsibility and collaboration through public-benefit initiatives such as food banks and urban greening[43]. Regarding local exploration, some regions abroad have attempted to incorporate community resources into primary and secondary environmental education systems. For example, they introduce public welfare curriculum modules and organize students to participate in local environmental campaigns and in school garden management, thereby strengthening practical skills and social responsibility[44][45]. Some universities have also experimented with community-based ecological design projects jointly undertaken by residents and international students, to enhance students' environmental action capacities in multicultural contexts[46].

Second, the literature also identifies significant challenges in community-based education. The first is short-termism resulting from weak institutional linkage. Volunteers often constitute the backbone of community participation initiatives; when government or environmental agencies face staffing constraints or lack stable funding, it becomes difficult to sustain long-term ecological civilization practice programs[47]. The second concerns limited openness and adaptability due to cultural differences. In local community projects, cognitive mismatches and ineffective communication between organizers and participants can undermine implementation and prevent initiatives from achieving intended outcomes. This challenge is particularly salient in communities with complex demographic compositions or large numbers of international students[48]. Third, disparities in resources and knowledge across communities often leave disadvantaged communities structurally weaker. To address these issues, improvements can be pursued along three dimensions: institutions, capacity building, and evaluation. For example, communities can better coordinate and pool project resources and establish mechanisms to recognize participation credits to strengthen students' motivation to engage. In addition, virtual community platforms can

be leveraged to provide students with online training in cross-cultural communication and environmental adaptive competence[49].

e. Green Development

Traditional models of economic growth are among the primary drivers of global nature loss[50]. Within its framework for education for sustainable development, the United Nations conceptualizes the economy, society, and the environment as an inseparable whole, advocating education as a means to promote a future that is environmentally sustainable, economically viable, and socially inclusive[51]. In ecological civilization education, green development foregrounds the interactive relationship between economic activity and environmental systems, and examines how education can guide the public toward a sustainable development mindset. Concepts such as the green and circular economies have increasingly been incorporated into educational discourse and practice. However, as Kosta et al. have noted, sustainability-related ideas remain underrepresented in basic education[52].

Green development education faces challenges similar to those found in other ecological civilization curricula, including fragmented content, underdeveloped practice mechanisms, and a disconnect between knowledge and institutional–cultural contexts. For green development in particular, three issues are especially salient. First, there is often insufficient logical coherence across curricular knowledge. For example, students may only develop a superficial understanding of how green finance relates to environmental ethics[53] Second, educational evaluation frequently lacks rigorous assessment mechanisms, and some "green campus" initiatives consequently devolve into largely symbolic, box-ticking exercises[54]. Third, there is a notable absence of a "Global South perspective" in the theory–practice nexus. This includes hegemonic tendencies in the construction of Western-centric discourses on green education, alongside the neglect of ecological knowledge and lived experiences in less developed regions—such as Indigenous ecological knowledge in tropical rainforest areas[55].

On this basis, green development education should adopt an integrated strategy that combines curriculum content, the construction of practice-based learning environments, and culturally diverse access. Drawing on Maslow's hierarchy of needs, the value dimensions of green development education can be structured as follows: environmental awareness addresses needs for safety and belonging, capacity building supports the development of self-esteem, and the

cultivation of ecological critical thinking corresponds to self-actualization .In addition, digital campus systems should be developed to visualize green management practices—such as carbon footprint monitoring and energy audits—and embed them into everyday learning contexts. At the institutional level, a green literacy evaluation framework can be established, for example, by using blockchain technology to document students' learning trajectories from knowledge acquisition to active participation[56]. Finally, to address the lack of cultural perspectives, diverse viewpoints should be incorporated to broaden students' understanding of global green diversity[57].

IV. Research Conclusions

In summary, research on ecological civilization education has continuously evolved through the interaction between global contexts and local practices, showing an overall trend of thematic expansion, diversified pathways, and deepened practice.

First, the themes of ecological civilization education research have expanded over time. From 2011 to 2018, studies were relatively concentrated, focusing on foundational issues such as climate change and sustainable development. Between 2019 and 2021, research gradually extended to higher education, urban conservation, and science education. From 2022 to 2024, the scope expanded rapidly to emerging topics such as digital technologies and green innovation, reflecting the field's responsiveness to social change and technological advancement.

Second, research on ecological civilization education has undergone a developmental process from foundational themes to practice-oriented expansion, and has since moved toward diversified integration. Early studies focused on fundamental issues such as social well-being and water resources. At the same time, the middle stage shifted attention to educational practices, including sustainability in higher education and community participation. In recent years, emerging topics, such as digital technologies and green innovation, have been increasingly integrated, reflecting growing diversity. Internally, this evolution demonstrates a systemic, multidimensional expansion, with stable research networks forming around social well-being, learning behaviors, and sustainable development, gradually extending to subject-based education and competency development. Traditional themes have been revitalized by new technologies, creating a pattern of stable cores with expanding peripheries, in which topics such as sustainability in higher education

play a bridging role. Externally, the evolution reflects the translation of concepts into practice, the digitalization of educational models, and the integration of disciplines. Research has increasingly addressed concrete issues such as waste management and green entrepreneurship, promoting linkages between ecological education and the green economy and indicating a shift from education toward broader social governance.

Finally, hotspot analysis indicates that climate change, green development, biodiversity conservation, sustainable consumption, and community participation are key research directions in ecological civilization education. Among these, climate change education serves as a core theme, emphasizing the enhancement of public climate awareness and action through interdisciplinary and action-oriented approaches. Education on food waste and sustainable consumption focuses on promoting resource conservation and transforming pro-environmental behaviors. In contrast, biodiversity education emphasizes interdisciplinary integration and experiential learning, fostering respect for nature and an understanding of ecosystem services. Community-based education strengthens ecological citizenship through local collaboration, while green development education promotes coordinated ecological and economic development. Despite extensive exploration across these themes, the field continues to face challenges such as fragmented curricula, disciplinary fragmentation, gaps between knowledge and practice, underdeveloped mechanisms, and limited cultural perspectives, underscoring the need for coordinated reforms at the policy, institutional, and pedagogical levels.

References：

[1]胡锦涛. 坚定不移沿着中国特色社会主义道路前进 为全面建成小康社会而奋斗——在中国共产党第十八次全国代表大会上的报告[M]. 北京：人民出版社，2012.

[2]刘贵华, 岳伟. 论教育在生态文明建设中的基础作用[J]. 教育研究, 2013, 34(12):10-17.

[3]陈时见, 刘雅琪. 全球生态文明教育研究的主要进展与发展趋势[J]. 西北师大学报(社会科学版), 2024, 61(05):81-90.

[4]任帅, 张志华. 基于CiteSpace的绿色教育研究热点及趋势可视化分析[J]. 绿色科技, 2021, 23(13):274-276.

[5]刘自强, 王效岳, 白如江. 多维度视角下学科主题演化可视化分析方法研究——以我国图书情报领域大数据研究为例[J]. 中国图书馆学报, 2016, 42(06):67-84.

[6]朱光, 潘高枝, 李凤景. 时序关联与结构表征视角下的信息隐私研究主题演化研究[J]. 情报科学, 2022, 40(04):127-137.

[7]刘雅姝, 张海涛, 徐海玲, 等. 多维特征融合的网络舆情突发事件演化话题图谱研究[J]. 情报学报, 2019, 38(08):798-806.

[8]关鹏, 王曰芬. 科技情报分析中 LDA 主题模型最优主题数确定方法研究[J]. 现代图书情报技术, 2016(09):42-50.

[9][11]周健, 张杰, 屈冉, 等. 基于 LDA 的国内外区块链主题挖掘与演化分析[J]. 情报杂志, 2021, 40(09):161-169.
[10]王鹏, 高铖, 陈晓美. 基于 LDA 模型的文本聚类研究[J]. 情报科学, 2015, 33(01):63-68.
[12]关鹏, 王曰芬. 基于 LDA 主题模型和生命周期理论的科学文献主题挖掘[J]. 情报学报, 2015, 34(03):286-299.
[13]Climate change education [EB/OL]. (2024) [2025-01-22] https://www.unesco.org/en/climate-change/education
[14][17] [19][60] Muccione, Veruska, Tracy Ewen, and Saeid Ashraf Vaghefi. A scoping review on climate change education. PLOS Climate, 2025, 4(1): e0000356.
[15][20] Cordero, Eugene C., Anne Marie Todd, and Diana Abellera. Climate change education and the ecological footprint. Bulletin of the American Meteorological Society, 2008, 89(6): 865–872.
[16][36][51] Servant-Miklos, Virginie. Environmental education and socio-ecological resilience. Environmental Education Research, 2022, 28(1):18–39.
[18]Is the Education System Overlooking Climate Change? [EB/OL]. (2024-01-25) [2025-01-22] https://earth.org
[21][35][40][44] Klemow, Kenneth, et al. Improving ecological education through a four-dimensional framework. Frontiers in Ecology & the Environment, 2019, 17(2).
[22] [58]Jorgenson, Simon N., Jennie C. Stephens, and Beth White. Environmental education in transition. The Journal of Environmental Education, 2019, 50(3): 160–171.
[23] [43][46] Tidball, Keith G., and Marianne E. Krasny. Urban environmental education. Cities and the Environment, 2011, 3(1):11.
[24] UN: 17% of all food available at consumer levels is wasted [EB/OL]. (2021-03-04) [2025-01-22] https://www.unep.org/...
[25] Sundin, Niina, et al. Sustainability assessment of educational approaches. Journal of Cleaner Production, 2024, 481:144196.
[26] Anholon R, Sigahi T F A C, Cazeri G T, et al. Training future managers. World, 2024, 5(2):155–172.
[27] Goswami, Deepa. Developing Student Food Waste Literacy. set: Research Information for Teachers, 2023, 3:11–18.
[28][30] Kara, Ali, and Maung K. Min. Gen Z consumers' sustainable consumption behaviors. International Journal of Sustainability in Higher Education, 2024, 25(1):124–142.
[29]Aydin, Gozde, et al. Food and nutrition education in Australian primary schools. Health Education, 2021, 121(4):451–464.
[31]Borsatto, Jaluza Maria Lima Silva, et al. "Aligning community outreach initiatives with SDGs in a higher education institution with artificial intelligence." Cleaner and Responsible Consumption 12(2024):100160
[32] Biodiversity – Protected, Utilized, and Globally Promoted [EB/OL]. (2023-09-06) [2025-01-22] https://sdg.iisd.org/...
[33] [57] [52] What you need to know about education for sustainable development [EB/OL]. (2021-03-04) [2025-01-22] https://www.unesco.org
[34][39] Saiful, Jepri Ali. Eco-ELT for environmental research and praxis in ELT. Journal on English as a Foreign Language, 2023, 13(2):373–398.
[37] [47] Muafiah, Evi, et al. The concept of eco-friendly schools. Journal of Physics: Conference Series, 2021, Vol. 1796(1).
[38] Koyama, Dennis, and Takehiro Watanabe. Why a dispositional view of ecological literacy is needed. Teaching in Higher Education, 2023, 28(5):1108–1117.
[41] Svarstad, Hanne. Critical climate education. International Studies in Sociology of Education, 2021, 30(1–2):214–232.
[42] Robertson, Jennifer L., and Julian Barling. Greening organizations. Journal of Organizational Behavior, 2013, 34(2):176–194.
[45] Brahma R. Innovations in teaching and learning for environmental education. Journal of the American Institute, 2025, 2(2):210–224.
[48][50] Uralovich, Kiyosov Sherzod, et al. A primary factor in sustainable development. Caspian Journal of Environmental Sciences, 2023, 21(4):965–975.
[49] Chan, Cecilia Ka Yuk. A comprehensive AI policy education framework. International Journal of Educational Technology in Higher Education, 2023, 20(1):38.

[54] Kosta, Aikaterini D., Kiriaki M. Keramitsoglou, and Konstantinos P. Tsagarakis. Circular economy and sustainable development in primary education. Frontiers in Sustainability, 2025, 6:1414055.

[55] [59] Akinsemolu A A, Onyeaka H. The role of green education in achieving the sustainable development goals. Renewable and Sustainable Energy Reviews, 2025, 210:115239.

[56] Khetagurova, Valeriya SHOTAEVNA, et al. Ecological education as a basis. Journal of Environmental Management and Tourism, 2015, 6(1):79.

[57] Stein, Sharon, et al. Beyond colonial futurities in climate education. Teaching in Higher Education, 2023, 28(5):987 – 1004.