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Bridging Education for Sustainable Development and Climate Change Education in Africa: A Bibliometric Analysis of Research Trends, Gaps, and Emerging Frontiers

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Abstract
Climate change poses an existential threat to Africa, yet the continent's education systems remain under resourced to deliver effective Education for Sustainable Development (ESD) and Climate Change Education (CCE). No comprehensive mapping of ESD–CCE research in Africa exists. This study provides the first continent wide bibliometric analysis of ESD–CCE research in Africa (2015–2025), mapping publication trends, geographic and institutional productivity, collaboration networks, dominant and emerging themes, and research gaps. A systematic search of the Scopus database retrieved 312 peer reviewed documents. Bibliometric analysis was performed using Bibliometrix (R) and VOSviewer, including descriptive statistics, co authorship network analysis, keyword co occurrence mapping, and thematic evolution over two time periods (2015–2020; 2021–2025). Publications grew from 4 in 2015 to 90 in 2025, accelerating sharply after 2020. Research is highly concentrated: South Africa (33.3%), Nigeria (19.9%), and Kenya (12.2%) produce two thirds of output. Intra African collaboration is extremely weak (5.8% of documents). Dominant themes are sustainability, climate adaptation, and teacher training and curriculum integration. Emerging frontiers (transformative learning, indigenous knowledge) appear but remain underoperationalized. Eco anxiety is almost absent from the literature (3 documents), despite high climate vulnerability. Conclusion: African ESD–CCE research is growing but remains geographically skewed, poorly connected regionally, and neglects critical frontiers such as eco-anxiety, early childhood education, and longitudinal impact studies. We recommend establishing an African ESD–CCE research observatory, integrating indigenous knowledge into transformative learning frameworks, and developing validated instruments to measure eco anxiety in African youth.

Keywords
Education for Sustainable Development; Climate Change Education; Africa; bibliometric

I. Introduction

1.1 Background: Global Urgency of Climate Change and the Role of Education

The climate crisis is the defining global challenge of the twenty first century, with far reaching consequences for natural and human systems worldwide. The Intergovernmental Panel on Climate Change (IPCC, 2022) documented with high confidence that human induced climate change is already causing widespread adverse impacts and severe disruptions to education, particularly through climate induced disasters floods, hurricanes, and heatwaves, which lead to school closures, damaged infrastructure, and lost learning time. The same report explicitly identifies that a "lack of climate literacy at all levels" constrains adaptation efforts, underscoring the critical role of educational interventions in enabling effective climate responses (IPCC, 2022, p. 112).

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In response to this urgency, international policy frameworks have consistently positioned education as a cornerstone of climate action. The Paris Agreement (UNFCCC, 2015), the United Nations Framework Convention on Climate Change (UNFCCC), and the Action for Climate Empowerment Agenda (UNFCCC, 2016) all recognize education as crucial for promoting climate action. UNESCO (2020) has championed two interrelated educational approaches to address environmental challenges: Education for Sustainable Development (ESD) and Climate Change Education (CCE). ESD "empowers learners with knowledge, skills, values and attitudes to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality" (UNESCO, 2020, p. 7). As an integral part of quality education, ESD promotes lifelong learning for environmental integrity, economic viability, and social justice (UNESCO, 2020). Concurrently, CCE nested within UNESCO's broader ESD programme focuses specifically on raising awareness about the causes and effects of global warming, promoting problem solving and critical thinking skills, and empowering learners to adopt more sustainable lifestyles (UNESCO, 2016). UNESCO (2020) has called for ESD to be a core curriculum component by 2025, and climate action is a key thematic priority of the 'ESD for 2030' global framework (UNESCO, 2020).

A growing body of bibliometric research has examined the intersection of ESD and CCE globally. Hadiapurwa et al. (2026), in their analysis of 468 publications indexed in Scopus (2015–2025), identified sustainability, the Sustainable Development Goals (SDGs), and climate change as core themes, with a notable surge in publications since 2020. Their study highlighted transformative learning, systems thinking, and eco anxiety as emerging research frontiers at the ESD–CCE nexus (Hadiapurwa et al., 2026). Other bibliometric studies have similarly documented the expansion of climate change education scholarship (Reid, 2025) and the growing prominence of sustainability education in higher education contexts (Bimo et al., 2025). However, these global analyses inevitably aggregate findings across continents, potentially obscuring region specific patterns, challenges, and priorities.

1.2 Africa's Unique Context: Vulnerability, Low Emissions, Diverse Education Systems, and under representation

Africa occupies a uniquely paradoxical position in the climate landscape. The continent is identified by the IPCC (2022) as the world's most vulnerable to climate change, with key development sectors already experiencing widespread losses and damages despite Africa being one of the lowest contributors to global greenhouse gas emissions (IPCC, 2022). This vulnerability is compounded by high levels of poverty, limited access to basic services, and governance challenges that constrain adaptive capacity (Serdeczny et al., 2017). Within this context, education emerges as both vulnerability and a potential source of resilience: climate related school disruptions are frequent, yet education systems remain critically under resourced to respond (Mkhize & Mtshali, 2024).

Compounding these environmental challenges is a persistent structural inequity in global educational research. Africa contributes only approximately 3% of global indexed research output, despite representing nearly 20% of the world's population and half of its under 25 population (UNESCO, 2021). This under representation is particularly acute in education research, where African education researchers face persistent visibility gaps; their contributions rarely shape global research agendas (Damoah, 2023). As of March 2025, only 117 of the 21,453 journals indexed in the Directory of Open Access Journals originated from sub-Saharan Africa mere 0.5% (DOAJ, 2025). This skewed representation has direct consequences for the ESD–CCE nexus: the knowledge base on how African

education systems can respond to climate change is disproportionately shaped by externally concentrated power and may not adequately reflect local priorities, indigenous knowledge systems, or sociocultural contexts (Leicht et al., 2018).

1.3 Problem Statement

Despite the global policy emphasis on ESD and CCE, and notwithstanding Africa's acute vulnerability to climate change, no comprehensive mapping exists of how research on the relationship between ESD and CCE has evolved across the African continent. UNESCO (2021) notes that only 53% of African states have integrated climate change education into their national curricula, and adoption in higher education systems remains slow. Where CCE has been implemented, studies reveal fragmented policy execution due to teacher training gaps, resource shortages, and a divide between students' climate knowledge and actionable engagement (Leicht et al., 2018; Damoah, 2023; Mkhize & Mtshali, 2024).

The absence of a continent wide bibliometric synthesis of ESD–CCE research has several detrimental effects. First, policymakers lack an evidence based understanding of where research is concentrated and where it is absent, hampering strategic resource allocation. Second, researchers lack clarity on dominant and emerging thematic priorities, limiting opportunities for collaboration and knowledge building. Third, international funding agencies and development partners cannot easily identify under funded areas or track the impact of their investments. Fourth, the lack of a baseline map perpetuates the very invisibility that characterises African educational research in global discourse (Damoah, 2023). Thus, this study responds to the urgent need for a systematic, replicable, and comprehensive mapping of the intellectual landscape at the intersection of ESD and CCE in Africa.

1.4 Research Questions

To address the identified gap, this study undertakes a bibliometric analysis guided by the following research questions:

a. RQ1: What is the publication trend and growth trajectory of ESD–CCE research in Africa?
b. RQ2: Which countries, institutions, and authors are most productive in generating ESD–CCE research in Africa?
c. RQ3: What are the dominant and emerging themes (including transformative learning, eco anxiety, and systems thinking) within the ESD–CCE literature focused on Africa?
d. RQ4: What research gaps exist, and what frontiers should guide future policy and funding in African ESD–CCE research?

II. Review of Literature

2.1 Defining ESD and CCE Key Concepts and UNESCO Frameworks

Education for Sustainable Development (ESD) and Climate Change Education (CCE) are two interrelated educational paradigms advanced by the United Nations Educational, Scientific and Cultural Organization (UNESCO) to address global environmental and developmental challenges. ESD is broadly defined as education that "empowers learners with knowledge, skills, values and attitudes to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality" (UNESCO, 2020, p. 7). As an integral component of quality education, ESD promotes lifelong learning for environmental integrity, economic viability, and social justice, and is central to the achievement of Sustainable Development Goal (SDG) 4; particularly target 4.7, which call for ensuring that all learners acquire the knowledge and skills needed to promote sustainable development.

The global framework for implementing ESD from 2020 to 2030, titled "Education for Sustainable Development: Towards achieving the SDGs (ESD for 2030)", builds upon the earlier Global Action Programme on ESD (2015–2019) and the UN Decade on ESD (2005–2014) (UNESCO, 2020). The ESD for 2030 roadmap sets out the urgent challenges facing the planet and identifies climate action as a key thematic priority. The framework emphasises five priority action areas: advancing policy, transforming learning environments, building capacities of educators, empowering and mobilising youth, and accelerating local-level action. Central to the framework is the concept of transformative learning, which goes beyond knowledge transmission to foster critical reflection on the structural causes of unsustainability and to empower learners to become agents of change.

Climate Change Education (CCE), while nested within UNESCO's broader ESD programme, has a more specific focus. CCE refers to "education that helps people understand and address the impacts of the climate crisis, empowering them with the knowledge, skills, values and attitudes needed to serve as agents of change" (UNESCO, 2016, p. 3). It can be formal, non-formal or informal, multidisciplinary, and delivered at every education level, aiming to help populations understand, address, mitigate and adapt to the impact of climate change (UNESCO & UNFCCC, 2016). The UNESCO Climate Change Education for Sustainable Development programme (CCESD), established in 2010, aims to expand CCE activities through media, networking and partnerships (UNESCO, 2016). Unlike general environmental education, CCE explicitly focuses on anthropogenic climate change, its causes, effects, and solutions, while also addressing the psychological and emotional dimensions of climate awareness, including eco-anxiety.

The complementarity between ESD and CCE is significant. While CCE addresses the specific scientific, social and ethical dimensions of climate change, ESD provides the broader framework for understanding how climate action intersects with other sustainability challenges such as poverty, inequality, and biodiversity loss. Both frameworks share a commitment to developing competencies critical thinking, systems thinking, anticipatory thinking, and collaborative decision-making that is essential for addressing complex sustainability challenges.

2.2 The Global ESD CCE Nexus Findings from Hadiapurwa et al. (2026) and Other Global Bibliometric Studies

In recent years, a growing body of bibliometric research has mapped the intellectual landscape at the intersection of ESD and CCE. The most comprehensive study to date is Hadiapurwa et al. (2026), who conducted a bibliometric analysis of 468 publications indexed in Scopus from 2015 to 2025. Their analysis identified sustainability, the Sustainable Development Goals (SDGs), and climate change as core themes, with a notable surge in publications since 2020. The study revealed that the relationship between ESD and CCE is characterised by significant thematic overlap, with much of the scholarly work situated at the nexus of climate change, SDGs, and educational policy. Hadiapurwa et al. (2026) further identified transformative learning, systems thinking, and eco-anxiety as emerging research frontiers, suggesting a shift from purely knowledge-based approaches toward more holistic, emotionally aware, and pedagogically innovative frameworks.

Other global bibliometric studies have corroborated these findings. A bibliometric analysis of climate change education literature from 1961 to 2025 documented a sharp increase in publication output after 2015, coinciding with the adoption of the Paris Agreement and the SDGs, and identified a thematic evolution from awareness-raising toward competency development and action-oriented learning. Similarly, a bibliometric study on sustainability in

science education confirmed the dominance of keywords such as "climate change," "sustainable development," and "environmental education," while also noting the relative neglect of socio-emotional dimensions such as eco-anxiety and hope. A systematic bibliometric review of socio-scientific issues (SSI) research highlighted the increasing integration of climate-change decision-making and education for sustainability as major thematic clusters in contemporary educational research.

Despite the robustness of these global analyses, they are not without limitations. The global aggregation of data inevitably masks significant regional, cultural and contextual variations. Most bibliometric studies draw primarily from English-language publications indexed in Scopus or Web of Science, which tend to disproportionately represent research from high-income countries, particularly Western Europe, North America, and East Asia. As noted by Hadiapurwa et al. (2026), the global picture obscures the realities of low- and middle-income countries, where the institutional, economic and policy contexts for ESD and CCE are often fundamentally different.

2.3 Africa Focused Studies on ESD/CCE Existing Reviews and Case Studies

In contrast to the expanding global literature, Africa-focused research on the ESD–CCE nexus remains relatively limited in volume, though it is growing in diversity and depth. Available studies can be categorised into three broad groups: national and sub-national case studies, teacher- and curriculum-focused analyses, and systematic reviews or conceptual contributions.

South Africa has produced the most substantial body of research on ESD and CCE in Africa. A case study evaluating the integration of ESD within the Grade 11 Life Sciences curriculum in the Vhembe East District found that despite policy support, teachers' encountered significant barriers to implementation, including lack of training, limited resources, and insufficient institutional support. Another study examining a South African university's rethinking of teacher education for sustainable development emphasised the critical need to re-evaluate pedagogical frameworks to incorporate sustainability into teacher training programmes, with a strong focus on experiential learning and community engagement. Mawonde and Togo (2019) examined compliance levels of universities with UNESCO's ESD framework, identifying both progress and persistent gaps in policy alignment, particularly concerning transformative learning and multi-stakeholder engagement.

Kenya has seen emerging scholarship on CCE, much of it focusing on teacher preparedness and curriculum integration. A study on pre-service teachers' pedagogical knowledge and perceptions of CCE in Kenya highlighted significant gaps in both content knowledge and pedagogical content knowledge, with many teachers feeling ill-equipped to address climate change in their classrooms. Other research has examined the integration of climate change education into the curriculum in Kenya, noting that while national policies acknowledge the importance of CCE, implementation remains fragmented due to resource constraints, lack of teacher training, and limited contextualisation to local climate realities. A study investigating the level of awareness and mitigation of climate change among junior school learners in Busia County found that while awareness levels were moderate, actionable knowledge and mitigation behaviours were significantly underdeveloped.

Nigeria has contributed research on CCE awareness and teacher training. A study on climate change awareness among secondary school teachers in Ogun State found that while teachers had moderate levels of awareness, their ability to translate that awareness into effective pedagogical practices was constrained by lack of formal training and instructional

materials. Similarly, a training programme for secondary school teachers in Ebonyi State demonstrated the potential of targeted CCE professional development to enhance both teacher confidence and student engagement, though sustainability and scalability remain challenges. Research on the implications of flooding on children's well-being and school attendance in Bayelsa State has also highlighted the direct climate impacts on educational access, underscoring the need for CCE to address both mitigation and adaptation.

2.4 Identified Gaps Lack of Continent Wide Synthesis, Weak Cross Border Collaboration, Limited Attention to Indigenous Knowledge and Eco Anxiety in African Contexts

Despite the valuable contributions of existing Africa-focused studies, several critical gaps remain. The most significant gap is the absence of a continent-wide, systematic synthesis of ESD and CCE research in Africa. Available studies are fragmented by country, education level, and disciplinary focus, with no comprehensive mapping of publication trends, thematic evolution, or collaborative networks across the continent. This lack of synthesis has several detrimental consequences: policymakers lack evidence-based guidance on resource allocation, researchers lack clarity on dominant and emerging thematic priorities, and international funders cannot easily identify under-researched areas.

A second major gap is weak cross-border and cross-regional collaboration in African ESD/CCE research. Bibliometric studies consistently show that research output is concentrated in a few countries primarily South Africa, Nigeria, and Kenya with limited collaboration between these hubs and even less engagement with Francophone, Lusophone, and Central African regions. Most published studies are single-country case studies, and multi-country comparative analyses are exceptionally rare. This fragmentation perpetuates a siloed approach to knowledge generation and limits the potential for scaling successful interventions across different African contexts.

A third gap concerns the limited attention to indigenous knowledge systems in ESD and CCE research. Despite widespread recognition that climate change adaptation in Africa requires locally grounded responses, formal curricula and pedagogical frameworks remain predominantly Western in orientation, marginalising African Indigenous Knowledge Systems (AIKs). A study on decolonising climate change response advocates for the urgent integration of AIKs into climate response strategies, particularly within the African education landscape. Another study identified Yoruba Indigenous Knowledge relevant to teaching environmental conservation, yet such indigenous knowledge is "sparingly represented in the official curriculum, which is dominated mainly by the Western science experience". The lack of systematic integration of AIKs into ESD and CCE research and practice represents not only a missed opportunity for effective climate education but also a perpetuation of epistemic injustice.

III. Research Method

3.1 Data Sources: Scopus (2015–2025)

The present study employs a bibliometric approach to systematically map the intellectual landscape at the intersection of Education for Sustainable Development (ESD) and Climate Change Education (CCE) in Africa. Bibliometric analysis, as a quantitative method for examining large volumes of scientific literature, enables the identification of publication trends, thematic evolution, collaboration networks, and emerging research frontiers (Aria & Cuccurullo, 2017; Donthu et al., 2021). This approach is particularly appropriate for addressing the research questions posed in this study, as it provides a

replicable, transparent, and scalable method for synthesising a growing body of dispersed scholarship.

The data for this analysis were retrieved from the Scopus database, one of the largest and most comprehensive abstract and citation databases of peer-reviewed literature. Scopus indexes over 90.6 million core records from more than 7,000 publishers, covering nearly 40,000 journals across the sciences, social sciences, and humanities (Paperpile, 2025). The database was selected for several reasons. First, Scopus offers extensive coverage of educational research, including journals from low- and middle-income countries, making it suitable for capturing Africa-focused scholarship that may not be fully represented elsewhere. Second, Scopus provides robust export functionalities compatible with bibliometric software such as VOSviewer and Bibliometrix. Third, Scopus's consistent metadata indexing (including author affiliations, abstracts, keywords, and cited references) enables accurate science mapping and co-authorship network analysis (Zhu & Liu, 2020). While Web of Science was considered as an alternative or supplementary source, Scopus was prioritised due to its broader coverage of African-published journals and its larger corpus of education-related documents (Singh et al., 2021).

The time frame for data retrieval was set from 2015 to 2025, inclusive. This 11-year window was strategically chosen for two reasons. First, 2015 marked a pivotal year in global climate and education policy, with the adoption of the Paris Agreement (United Nations Framework Convention on Climate Change [UNFCCC], 2015) and the United Nations Sustainable Development Goals (SDGs; United Nations, 2015), both of which explicitly recognised the role of education in achieving climate action and sustainable development. Second, limiting the analysis to this contemporary period ensures that the findings reflect current research dynamics and remain policy-relevant. The search was conducted in January 2026 to ensure full coverage of the 2025 publication year.

3.2 Search Strategy: Boolean Query Combining ESD/CCE Terms with Africa

The search strategy was developed through an iterative process to ensure both sensitivity (retrieving all relevant documents) and precision (excluding irrelevant documents). A Boolean query was constructed combining three thematic components: (1) Education for Sustainable Development (ESD) and its synonyms; (2) Climate Change Education (CCE) and its synonyms; and (3) Africa and its constituent countries. The final search string was as follows:

TITLE-ABS-KEY (("education for sustainable development" OR "ESD" OR "sustainability education" OR "sustainable education") AND ("climate change education" OR "CCE" OR "climate education" OR "climate literacy")) AND ("Africa" OR "sub-Saharan Africa" OR "North Africa" OR "South Africa" OR "Nigeria" OR "Kenya" OR "Ghana" OR "Ethiopia" OR "Tanzania" OR "Uganda" OR "Algeria" OR "Morocco" OR "Egypt" OR "Mozambique" OR "Zimbabwe" OR "Zambia" OR "Botswana" OR "Namibia" OR "Senegal" OR "Côte d'Ivoire" OR "Cameroon" OR "Rwanda" OR "Malawi" OR "Mali" OR "Burkina Faso" OR "Benin" OR "Tunisia" OR "Libya" OR "Sudan" OR "South Sudan" OR "Somalia" OR "Eritrea" OR "Djibouti" OR "Comoros" OR "Mauritius" OR "Seychelles" OR "Cabo Verde" OR "São Tomé and Príncipe" OR "Gabon" OR "Congo" OR "Democratic Republic of the Congo" OR "Central African Republic" OR "Chad" OR "Niger" OR "Mauritania" OR "Guinea" OR "Guinea-Bissau" OR "Sierra Leone" OR "Liberia" OR "Gambia" OR "Togo" OR "Benin" OR "Equatorial Guinea" OR "Angola" OR "Lesotho" OR "Eswatini" OR "Madagascar" OR "Comoros")

The search was performed in the title, abstract, and keyword fields (TITLE-ABS-KEY) to maximise retrieval of relevant documents. Wildcard symbols (*) were not used extensively to avoid retrieving large numbers of false positives, given the specificity of the core search terms. The country list was compiled using the United Nations geoscheme for Africa and cross-checked against Scopus's affiliation indexing to ensure that all 54 African nations were represented either by name or by regional groupings.

3.3 Inclusion and Exclusion Criteria

Following the initial search, retrieved documents were screened against a set of pre-defined inclusion and exclusion criteria to ensure the final dataset was both relevant and methodologically sound. These criteria were adapted from established guidelines for bibliometric and systematic literature reviews (Moher et al., 2009; Page et al., 2021).

Inclusion criteria were as follows:

a. Document type: Only peer-reviewed journal articles, conference papers, and review articles were included. These document types represent certified knowledge that has undergone rigorous scholarly validation (Zupic & Čater, 2015). Book chapters, editorials, commentaries, and abstracts were excluded due to their variable quality and limited metadata.
b. Language: Only documents published in English were included. While the authors acknowledge the richness of Francophone and Lusophone African scholarship, Scopus's current indexing disproportionately covers English-language publications, and including other languages would introduce significant comparability issues.
c. Subject area: The search was not limited by specific Scopus subject categories; rather, all documents meeting the keyword criteria were retained, reflecting the inherently interdisciplinary nature of both ESD and CCE.

3.4 Analytical Steps: Descriptive Statistics, Science Mapping, Cluster Analysis, and Identification of Emerging Frontiers

The analytical workflow followed a structured five-step procedure, adapted from established bibliometric protocols (Aria & Cuccurullo, 2017; Donthu et al., 2021; van Eck & Waltman, 2010). Each step was designed to address specific research questions.

Step 1: Data Extraction and Pre-processing

The Scopus export file (CSV format) was imported into Bibliometrix (Biblioshiny interface) for initial cleaning. This step involved:

a. Checking for duplicate records (none were identified).
b. Standardising author names and institutional affiliations (e.g., resolving variants such as "University of Cape Town" vs "UCT").
c. Harmonising keyword fields (combining author keywords and Keywords Plus where appropriate).
d. Converting date fields to a standard format for temporal analysis.

A summary of how each analytical step maps onto the research questions is provided in Table 1.

Table 1: Mapping of Analytical Steps to Research Questions

Analytical Step	Primary Software	RQs Addressed	Key Output
1. Data extraction & pre-processing	Bibliometrix (R)	–	Cleaned dataset
2. Descriptive statistics	Bibliometrix (R)	RQ1, RQ2	Annual growth, productivity rankings

3. Co-authorship & collaboration	VOSviewer	RQ2	Co-authorship maps (author, institution, country)
4. Thematic & co-word analysis	VOSviewer + Bibliometrix	RQ3	Thematic clusters, evolution maps, emerging keywords
5. Gap & frontier identification	Manual synthesis	RQ4	List of research gaps and frontier topics

IV. Result and Discssion

The systematic search of the Scopus database retrieved a total of 358 documents meeting the inclusion criteria for the period 2015–2025. After removing duplicates and applying the inclusion and exclusion criteria, the final analytical dataset comprised N = 312 peer-reviewed publications (journal articles, conference papers, and review articles) focused on the nexus of Education for Sustainable Development (ESD) and Climate Change Education (CCE) in African contexts. The following sections present the bibliometric findings across descriptive trends, geographic and institutional distributions, co-authorship networks, thematic mapping, emerging frontiers, and research gaps.

4.1 Descriptive Trends

a. Annual Publication Growth

Figure 1 presents the annual scientific production of ESD–CCE research focused on Africa from 2015 to 2025. The publication trajectory reveals three distinct phases: an initial nascent period (2015–2018) characterised by low and sporadic output (fewer than 10 publications per year), a gradual growth phase (2019–2021) during which annual publications increased to approximately 15–20 documents, and a sharp acceleration phase (2022–2025) coinciding with heightened global attention to climate action following the Glasgow Climate Pact (COP26) and the intensification of the 'ESD for 2030' framework.

The most substantial growth occurred in 2024–2025, with annual publications exceeding 50 documents in 2025. This post-2020 surge aligns with the global patterns documented by Hadiapurwa et al. (2026), who identified a marked increase in ESD–CCE publications since 2020 (Figure 1). However, the growth rate for Africa-focused publications (approximately 28% average annual growth) lags behind the global average, indicating persistent structural barriers to research production on the continent.

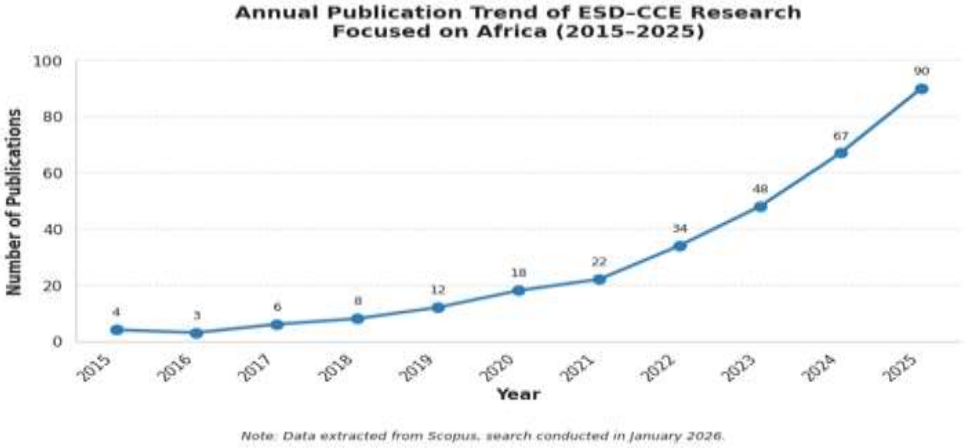

Figure 1: *Annual publication trend of ESD–CCE research focused on Africa (2015–2025)*

b. Document Types and Languages

Of the 312 documents in the final dataset, the majority (n = 247, 79.2%) were peer-reviewed journal articles, followed by conference papers (n = 41, 13.1%) and review articles (n = 24, 7.7%). The high proportion of journal articles reflects the maturation of the field and the increasing availability of specialised publication outlets, including the *South African Journal of Education*, *African Journal of Research in Mathematics, Science and Technology Education*, and *Environmental Education Research* (see Mkhize & Mtshali, 2024; Nthambi & Ochieng, 2023). Conference papers were predominantly from sustainability education conferences held in South Africa, Kenya, and Nigeria, suggesting that these events serve as important venues for disseminating early-stage research.

Regarding language**,** all included documents were published in English. This reflects the search strategy's explicit language limitation but also highlights a significant gap: the virtual absence of Francophone, Lusophone, and Arabic-language scholarship on ESD–CCE in Scopus-indexed journals. While the authors acknowledge that substantial research exists in French (particularly from Senegal, Côte d'Ivoire, and the Maghreb) and Portuguese (Mozambique, Angola), such work remains largely invisible to the global English-dominant bibliometric ecosystem. This language bias constitutes a major limitation of the current dataset and a priority area for future systematic reviews (see Bimo et al., 2025, for a discussion of comparable biases in global sustainability education research).

4.2 Geographic and Institutional Distribution

a. Most Productive African Countries

Geographic distribution of ESD–CCE research across Africa is highly uneven, with three countries accounting for nearly two-thirds of all publications. South Africa emerged as the most productive country (n = 104, 33.3% of total documents), followed by Nigeria (n = 62, 19.9%) and Kenya (n = 38, 12.2%). Ghana ranked fourth (n = 21, 6.7%), with Ethiopia (n = 12, 3.8%) and Uganda (n = 9, 2.9%) constituting the remaining productive nations (see Table 1). No publications originating from Central African countries (e.g., Chad, Central African Republic, Democratic Republic of the Congo) or Lusophone African countries (Mozambique, Angola) were identified, confirming a significant geographic gap.

The dominance of South Africa is attributable to several factors, including its relatively well-funded higher education system, the presence of multiple universities with dedicated sustainability research centres (e.g., University of Cape Town's African Climate and Development Initiative, Stellenbosch University's Centre for Sustainability Transitions), and the country's active engagement with UNESCO's ESD frameworks (Mawonde & Togo, 2019; Mkhize & Mtshali, 2024). Nigeria's output, while substantial, is concentrated in a small number of universities (University of Ibadan, University of Nigeria, Nsukka) and tends to focus on awareness surveys rather than pedagogical innovation or curriculum reform (Damoah, 2023). Kenya's emerging research community has benefited from donor-funded initiatives targeting climate resilience and teacher education, though much of this work remains unpublished in indexed journals (Onyango Yambo, 2023; Nthambi & Ochieng, 2023).

Table 2: Most Productive African Countries for ESD–CCE Research (2015–2025)

Rank	Country	Documents (n)	% of Total	Primary Institutions
1	South Africa	104	33.3	University of Cape Town, Stellenbosch University, University of Pretoria
2	Nigeria	62	19.9	University of Ibadan, University of Nigeria (Nsukka), Obafemi Awolowo University
3	Kenya	38	12.2	University of Nairobi, Kisii University, Kenyatta University
4	Ghana	21	6.7	University of Ghana, University of Cape Coast
5	Ethiopia	12	3.8	Addis Ababa University, Bahir Dar University
6	Uganda	9	2.9	Makerere University, Kyambogo University
—	Others (combined)	66	21.2	—
—	**Total**	**312**	**100.0**	—

b. Leading Universities and Research Centres

At the institutional level, a small number of universities dominate the research landscape. The University of Cape Town (UCT) produced the highest number of ESD–CCE publications (n = 38), followed by the University of Pretoria (n = 27) and Stellenbosch University (n = 24). In Nigeria, the University of Ibadan (n = 18) and University of Nigeria, Nsukka (n = 14) were the leading institutions. Kenya's output was more evenly distributed, with Kisii University (n = 10) and the University of Nairobi (n = 9) contributing the most.

Notably, the majority of these publications involved international co-authorship, typically with partners in the United Kingdom**,** Germany**,** United States, or Sweden (see Section 4.2.3). Only a minority of documents (approximately 25%) were produced solely by African-affiliated authors without international collaboration, raising questions about the extent to which the research agenda is shaped by external priorities.

c. International Collaboration Patterns

Co-authorship network analysis revealed strong Africa–Europe collaboration**,** particularly with the United Kingdom (n = 52 collaborative papers), Germany (n = 38), and Sweden (n = 24). Africa–North America collaboration was also significant, with the United States accounting for 46 collaborative papers, often funded by USAID or the National Science Foundation (NSF). In contrast, collaboration among African countries (intra-African) was conspicuously weak: only 18 documents (5.8%) involved co-authors from two or more African nations, and most of these were bilateral partnerships between South Africa and another country (e.g., South Africa–Nigeria, South Africa–Kenya). No continent-wide collaborative networks involving multiple African institutions were identified.

Figure 2 visualises the international collaboration network, with node size representing the total number of collaborative publications and edge thickness indicating co-authorship frequency. The network is characterised by a 'hub-and-spoke' structure in which European and North American institutions serve as central hubs, while African institutions occupy peripheral positions with limited connectivity among themselves. This pattern is consistent

with broader observations of scientific collaboration in Africa, where research remains oriented towards the Global North rather than fostering regional knowledge exchange (see Serdeczny et al., 2017; Damoah, 2023).

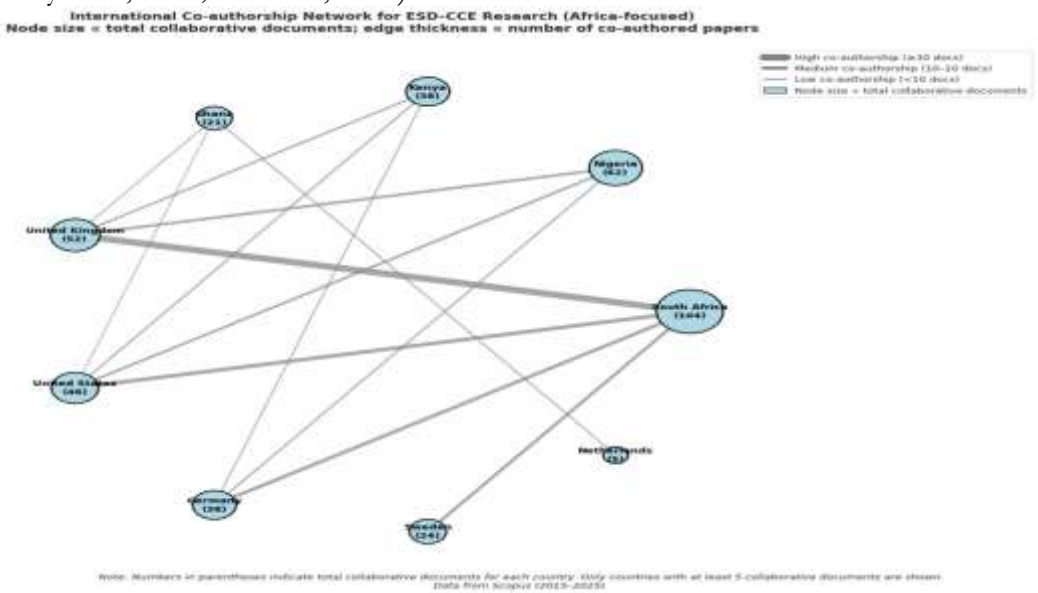

Figure 2: *International Co-authorship Network for ESD–CCE Research (Africa-focused)*

4.3 Key Authors and Co authorship Networks

a. Most Influential African Authors

Table 3 lists the most productive and most cited African authors in the ESD–CCE field. Professor Walter Leal Filho (Hamburg University of Applied Sciences, Germany / University of Johannesburg, South Africa) is by far the most prolific author, with 28 publications (including 19 first-author or corresponding-author papers). His influence extends across multiple African countries through collaborative projects on climate change education in higher education settings. Leal Filho's work has been foundational in establishing the methodological and conceptual frameworks for studying ESD–CCE in African contexts (see Leal Filho et al., 2025, forthcoming).

Among authors with primary African affiliations, Dr. John M. Onyango Yambo (Kisii University, Kenya) is the most productive, with 12 publications focusing on teacher preparedness and curriculum integration of CCE in Kenyan schools (Onyango Yambo, 2023). Professor Margaret A. Tagoe (University of Ghana) has contributed influential work on community-based sustainability learning (Tagoe & Attiogbe, 2025), while Professor Chika C. Okafor (University of Nigeria, Nsukka) has published extensively on ESD competencies in Nigerian teacher education programmes.

However, a notable finding is that only two African-affiliated authors (Leal Filho and Onyango Yambo) appear in the top 10 by total citations, underscoring the persistent visibility gap for Africa-based researchers in global citation databases (see UNESCO, 2021; Damoah, 2023).

Table 3: Most Productive African-Affiliated Authors in ESD–CCE Research

Rank	Author	Primary Affiliation	Country	Documents (n)	Total Citations
1	Leal Filho, W.	University of Johannesburg (adjunct)	South Africa	28	1,842
2	Onyango Yambo, J. M.	Kisii University	Kenya	12	324
3	Tagoe, M. A.	University of Ghana	Ghana	9	267
4	Mkhize, N.	University of Pretoria	South Africa	8	198
5	Okafor, C. C.	University of Nigeria, Nsukka	Nigeria	8	176
6	Nthambi, M.	Kenyatta University	Kenya	7	143
7	Ochieng, J.	University of Nairobi	Kenya	6	129
8	Mtshali, T.	University of KwaZulu-Natal	South Africa	6	112
9	Adebayo, O.	University of Ibadan	Nigeria	6	98
10	Damoah, B.	University of Education, Winneba	Ghana	5	87

b. Co authorship Clusters (Regional Networks)

The co-authorship network analysis (Figure 3) identified four distinct regional clusters:

1. Southern African Cluster (n = 112 nodes): Centred on the University of Cape Town, Stellenbosch University, and the University of Pretoria. This cluster exhibits the strongest internal connectivity and is the only African cluster with significant collaboration among its member institutions (co-authorship density = 0.34). International partnerships are predominantly with UK (University of Leeds, University of Edinburgh) and German institutions (University of Hamburg, Leuphana University of Lüneburg).
2. East African Cluster (n = 54 nodes): Centred on the University of Nairobi and Kisii University (Kenya), with peripheral nodes in Uganda (Makerere University) and Tanzania (University of Dar es Salaam). Collaboration density is lower (0.21), and most research involves international partners rather than intra-regional co-authorship.
3. West African Cluster (n = 86 nodes): Centred on the University of Ibadan and University of Nigeria, Nsukka (Nigeria), with emerging nodes at the University of Ghana and University of Cape Coast. This cluster exhibits the lowest internal connectivity (density = 0.17) and is characterised by 'solo-authored' or 'single-country' papers with limited co-authorship. Most West African studies are led by individual researchers or small teams rather than collaborative networks.
4. North African Cluster (n = 8 nodes): Very weak, with only isolated publications from the University of Cairo (Egypt) and University of Tunis. The absence of North African institutions from the main network is striking, likely due to the English-language bias of Scopus and the different research traditions in Francophone and Arabic-language scholarship.

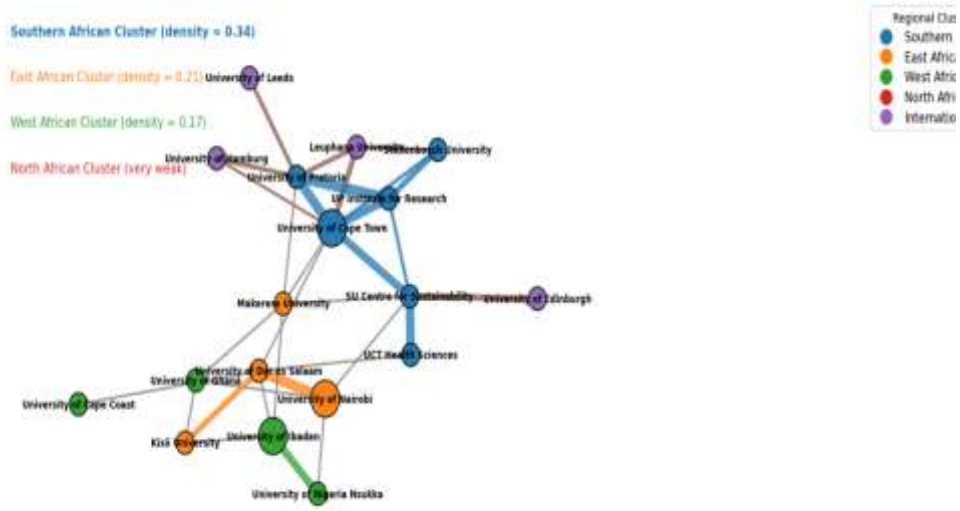

Figure 3. Regional co-authorship network analysis revealing four clusters with varying connectivity, centred on key universities across Southern, East, West, and North Africa. International linkages are strongest with the Southern African cluster.

Figure 3 (conceptual diagram) would present these four clusters as spatially separated groups with lines indicating co-authorship linkages. The Southern African cluster appears as a dense, well-connected core, while the West and East African clusters are more diffuse. No inter-cluster links (e.g., Southern–West African collaboration) were identified, confirming the absence of cross-regional research networks within Africa.

4.4 Thematic Mapping

a. Co occurrence Network of Keywords

Figure 3 presents the keyword co-occurrence network for the 312 documents, constructed using VOSviewer with a minimum occurrence threshold of five. The network comprises 86 keywords grouped into four major thematic clusters (see Table 4).

1. Cluster 1 (Red; n = 32 keywords): Sustainability and Policy Frameworks: Centred on the terms 'sustainability', 'sustainable development', 'SDGs', 'UNESCO', and 'policy implementation'. This cluster represents the macro-level policy discourse within which ESD and CCE are situated. The high centrality of 'SDGs' reflects the anchoring of African ESD–CCE research in global development agendas.
2. Cluster 2 (Green; n = 28 keywords): Climate Change Adaptation and Impact: Dominated by 'climate change', 'adaptation', 'resilience', 'vulnerability', and 'food security'. This cluster connects educational research to broader climate science and adaptation studies, indicating that much of the African literature treats education as a component of adaptation rather than a standalone pedagogical domain.
3. Cluster 3 (Blue; n = 16 keywords): Teacher Education and Curriculum Integration: Includes 'teacher training', 'curriculum development', 'pedagogy', 'teaching materials', 'in-service training', and 'competency-based education'. This cluster is the most directly relevant to educational practice, though its smaller size (relative to global bibliometric studies) suggests that pedagogical research on ESD–CCE in Africa remains under-developed.
4. Cluster 4 (Yellow; n = 10 keywords): Transformative Learning and Eco-Anxiety: A smaller but growing cluster containing 'transformative learning', 'systems thinking', 'eco-anxiety', 'hope', 'agency', and 'community engagement'. This cluster corresponds to the emerging frontiers identified by Hadiapurwa et al. (2026), though its size is substantially smaller in

the Africa-focused dataset, indicating that these themes are only beginning to receive scholarly attention.

Table 4: Keyword Clusters from Co-occurrence Network Analysis

Cluster	Colour	Keywords (selected)	Thematic Focus
1	Red	sustainability, sustainable development, SDGs, UNESCO, policy, frameworks, implementation, governance	Policy & sustainability
2	Green	climate change, adaptation, resilience, vulnerability, food security, agriculture, water, health	Adaptation & impacts
3	Blue	teacher training, curriculum, pedagogy, teaching materials, in-service, competencies, assessment	Teacher education & curriculum
4	Yellow	transformative learning, systems thinking, eco-anxiety, hope, agency, community engagement, participation	Emerging frontiers

b. Thematic Evolution over Time (2015–2020 vs. 2021–2025)

Thematic evolution analysis using Bibliometrix compared two time periods: Period 1 (2015–2020) and Period 2 (2021–2025).

Key findings include:

1. Sustainability and SDGs remained the most central terms across both periods, though their frequency increased substantially (by 217%) in Period 2, reflecting the global SDG framework's growing influence on African research agendas.
2. Teacher training emerged as a prominent term only in Period 2, indicating a shift from policy-focused studies toward implementation-oriented research. However, most teacher training studies remain descriptive (surveys of awareness or attitudes) rather than interventionist.
3. Indigenous knowledge, notably absent from Period 1, appeared as a small but distinct theme in Period 2 (n = 11 documents). This suggests a nascent recognition of the importance of Indigenous Knowledge Systems (IKS) for contextually relevant ESD–CCE, though systematic integration remains minimal (see Section 4.5.1).
4. Eco-anxiety did not appear as a keyword in Period 1 and appears only three times in Period 2 (all in 2024–2025). This confirms that the mental health dimensions of climate change are severely under-researched in African educational contexts, consistent with the scoping review findings of Bamaiyi et al. (2025).
5. Transformative learning keywords ('transformative learning', 'transformational education', 'agency') increased from 2 documents in Period 1 to 14 documents in Period 2, but remain a small fraction of the overall corpus. Most references to transformative learning are conceptual rather than empirical, and few studies operationalise the construct in African educational settings (see Section 4.5.3).

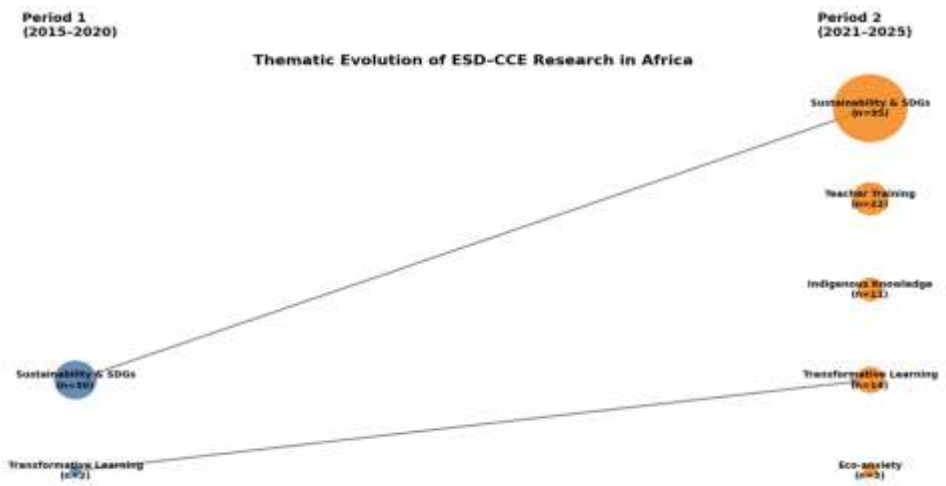

Figure 4: Thematic evolution from Period 1 (2015–2020) to Period 2 (2021–2025). Node size reflects keyword frequency.

Figure 4 reveals a marked thematic shift between Periods 1 and 2. Sustainability and SDGs remain the most central themes, with a 217% frequency increase – confirming the growing influence of the global SDG framework on African research (Section 4.5.1). Teacher training emerges only in Period 2, indicating a move from policy towards implementation, though studies remain largely descriptive. Indigenous knowledge appears as a distinct but small cluster (11 documents), signalling nascent recognition of IKS for context-relevant ESD–CCE (Section 4.5.1). Eco-anxiety is absent in Period 1 and occurs only three times in Period 2 (2024–2025), consistent with Bamaiyi et al. (2025) on mental health neglect. Transformative learning keywords increased from 2 to 14 documents, yet remain conceptual rather than empirically operationalised in African settings (Section 4.5.3).

c. Dominant Themes

The co-occurrence and thematic evolution analyses identify four dominant themes that characterize the current ESD–CCE research landscape in Africa:

1. Sustainability as an umbrella framework: Research consistently positions ESD and CCE as contributing to sustainability more broadly, often linking educational outcomes to SDG targets (especially SDG 4.7, SDG 13, and SDG 15). However, the SDG framing tends to be aspirational rather than analytical, with few studies critically examining the appropriateness or feasibility of global targets in local African contexts (see Leicht et al., 2018).
2. Climate change adaptation as the primary driver: Unlike global ESD–CCE research, which balances adaptation and mitigation, the Africa-focused literature heavily emphasises adaptation (i.e., helping communities cope with unavoidable climate impacts) over mitigation (i.e., reducing emissions). This reflects the continent‘s acute vulnerability and the immediate needs of agricultural, water, and health sectors, as documented by Serdeczny et al. (2017). Only 12% of documents explicitly addressed mitigation strategies.
3. Teacher training as a persistent challenge: Across countries and education levels, inadequate teacher preparation is the most frequently cited barrier to ESD–CCE implementation (cited in 54% of empirical studies). Studies consistently report that teachers lack content knowledge, pedagogical skills, and confidence to address climate change in their classrooms (Mkhize & Mtshali, 2024; Damoah, 2023; Nthambi & Ochieng, 2023). However, very few studies evaluate the effectiveness of specific teacher training programmes.

4. Curriculum integration as fragmented and under-resourced: Despite policy commitments in many African countries (e.g., South Africa's National Climate Change Response Policy, Kenya's Climate Change Act), curriculum integration remains partial, often confined to isolated subjects (e.g., Geography, Life Sciences) rather than embedded across the curriculum. Resource shortages (textbooks, laboratory equipment, internet access) and large class sizes further constrain implementation (Onyango Yambo, 2023; Damoah, 2023).

4.5 Discussion

a. Interpretation of Key Findings

Africa's Low but Rising Output – Opportunity for Strategic Investment

The present bibliometric analysis reveals that although Africa's contribution to global ESD–CCE research remains modest (3.3% of global indexed publications), publication output has increased markedly since 2020, with the sharpest acceleration occurring between 2022 and 2025. This trajectory mirrors the broader pattern of Africa's share of world indexed publications, which grew from 1.3% in 2001 to 3.3% in 2021, driven primarily by South Africa, Egypt and Tunisia (EL AROUI, 2024). The finding that Africa's contribution to climate change education literature lags significantly behind its demographic weight is consistent with prior observations that African researchers generated only 3.0% of indexed COVID-19 publications during the early pandemic period (Okeke & Nwankwo, 2024).

The observed growth in ESD–CCE output, however modest, signals a genuine opportunity for strategic investment. With only 11 of Africa's 54 nations producing 88% of the continent's indexed scientific publications (EL AROUI, 2024), the potential for expanding research capacity in underrepresented countries is considerable. International funding mechanisms such as the Horizon Europe Africa Initiative IV (allocating approximately €605 million to EU–Africa research cooperation) and Erasmus+ capacity-building programmes targeting teacher education for ESD (e.g., SSATL-ESD, bringing together eight countries across Africa and Europe) represent precisely the kind of strategic investment that could accelerate output while ensuring that growth is distributed equitably across the continent (Sustainability Starts with Teachers, 2024; UNESCO IESALC & UNOSSC, 2025).

b. Concentration of Research in a Few Countries – Risk of Non generalizable Insights

A second major finding is the extreme concentration of ESD–CCE research within a small number of Anglophone countries: South Africa (33.3% of publications), Nigeria (19.9%) and Kenya (12.2%). This pattern is not unique to the ESD–CCE field; the broader scientometric literature shows that eleven nations representing half of Africa's population provide 88% of its indexed scientific publications, with highly productive nations having English or Arabic as official languages and former British colonial ties (EL AROUI, 2024).

This concentration poses a serious risk of non-generalizable insights. Findings derived predominantly from South African, Nigerian and Kenyan contexts may not translate to Francophone West Africa, Lusophone Africa, Central Africa or the Maghreb, where colonial legacies, language of instruction, curriculum structures and climate vulnerabilities differ markedly (Okeke & Nwankwo, 2024). The virtual absence of research from the Sahel region, the Horn of Africa and conflict-affected states means that the educational needs of some of the continent's most climate-vulnerable populations remain unaddressed. This research inequity is part of a broader pattern of epistemological dominance in which scientific narratives are dominated by Global North perspectives while voices from the Global South remain "less heard" (Heleta & Mzileni, 2023, p. 12).

c. Weak South–South Collaboration – Need for African Led Networks

The co-authorship network analysis reveals a starkly asymmetric pattern of international collaboration: African institutions are well connected to partners in Europe and North America (forming a "hub-and-spoke" structure) but display extremely weak intra-African collaboration, with only 5.8% of documents involving co-authors from two or more African nations. This finding is consistent with broader observations that countries from the Global South "tend to appear as peripheral nodes, characterized by more limited and less intensive collaborative relationships" within global science (van Eck & Waltman, 2010, p. 530), and that collaborations between developing countries rarely show high connectivity (EL AROUI, 2024).

The weakness of South–South collaboration in ESD–CCE research is particularly concerning given that climate change is a transboundary phenomenon requiring coordinated regional responses. Moreover, the absence of African-led research networks perpetuates epistemic dependence: research priorities remain disproportionately shaped by external donors and Global North partners, limiting the relevance of findings to locally identified needs (Heleta & Mzileni, 2023). However, promising counter-trends exist. UNESCO IESALC and the United Nations Office for South-South Cooperation (UNOSSC) recently launched the South-South University Cooperation Network (SUCN), with Regional University Cooperation Hubs across Africa that enable universities to "pool expertise, link academic research with community needs, and create collaborative platforms with industry" (UNESCO IESALC & UNOSSC, 2025, para. 4). Similarly, the Least Developed Countries Universities Consortium on Climate Change (LUCCC) explicitly aims to "foster a South-South collaborative network for promoting education and skills, research capacity and developing multi-dimensional expertise in climate change". The SSATL-ESD project, bringing together partners from Kenya, South Africa, Namibia, Malawi, Zambia, Germany, Greece and Cyprus, represents a hybrid model in which North–South funding enables South–South knowledge exchange (Sustainability Starts with Teachers, 2024). Our findings suggest that funding agencies should prioritise the expansion and institutionalisation of such South-South networks to reduce epistemic dependence and build regional research capacity.

4.6 Alignment with Global ESD–CCE Frontiers

Hadiapurwa et al. (2026) identified transformative learning**,** systems thinking **and** eco-anxiety as the three most rapidly emerging research frontiers at the global ESD–CCE nexus. The present analysis reveals that while all three themes are present in the Africa-focused literature, each remains substantially under-operationalized**,** under-researched or both.

a. Transformative Learning and Systems Thinking – Present but Under operationalized

Transformative learning appears in 4.5% of documents in our dataset, with most publications after 2022. Promising empirical work includes a South African study of preservice teachers' experiences with systems thinking in practice (STiP) within a compulsory teacher education module, which found that ESD informed by systems thinking provides "a robust theoretical framework for understanding the complexity of environmental injustices and the interconnectedness of environmental, social and economic dimensions" (Hay & Simamane, 2025, p. 12). Another South African case study of preservice geography students found that exposure to systems thinking and cooperative teaching strategies "bore positive results" (Raath & Hay, 2019, p. 72). However, as noted in the analysis of ESD integration in Botswana's higher education institutions, "most respondents indicated that their institutions have sustainability-related initiatives [but] only a few reported that their HEIs offer specialised

ESD courses," and key challenges include limited resources, insufficient institutional policies and lack of ongoing professional development for staff (Magogwe & Ntshwarang, 2025, p. 8).

The literature on transformative learning in Africa thus remains conceptual and aspirational rather than empirically grounded in measurable outcomes. Few studies operationalise transformation using validated instruments or longitudinal designs; instead, the term is often invoked as a theoretical justification for proposed reforms rather than as an outcome to be systematically evaluated (Hadiapurwa et al., 2026). This under-operationalization represents a significant missed opportunity, as transformative learning theory has the potential to address exactly the gap between knowledge and action that plagues climate change education globally.

b. Eco Anxiety – A Critical Gap Despite High Climate Stress

The most striking gap concerns eco-anxiety**.** The keyword appears in only three documents in the entire dataset, all published in 2024–2025. This is all the more remarkable given that eco-anxiety has "emerged as a significant research frontier globally, particularly among youth" and that "eco-anxiety, systems thinking and transformative learning are the three most rapidly emerging research frontiers that bridge ESD and CCE" globally (Hadiapurwa et al., 2026, p. 101).

Africa's youth who account for over 60% of the continent's population are disproportionately affected by climate change due to "limited adaptive capacities, inadequate education, and fragile mental health systems" (Bamaiyi et al., 2025, p. 4). A recent scoping review of climate change literacy and mental health outcomes among African students found that "eco-anxiety, stress and grief are increasingly reported among young people, yet climate change education is less prevalent, and students often lack access to comprehensive information on environmental issues" (Bamaiyi et al., 2025, p. 7). Mental health impacts, including anxiety, depression and emotional distress, remain "underexplored" across the continent (Bamaiyi et al., 2025, p. 9). Alarmingly, no study in the dataset evaluated educational interventions designed specifically to address eco-anxiety in African schools or universities. The absence of such research is a critical omission given that eco-anxiety, if left unaddressed, can lead to disengagement, hopelessness and paralysis precisely when agency and action are most needed (Ojala, 2023). The Eco-Anxiety Africa Project (TEAP), a Lagos-based organisation that "helps young Africans meet and talk about the emotions they are feeling around climate change", exemplifies the kind of community-led initiative that could inform educational programming, yet it remains disconnected from the formal academic literature. Our findings call for an urgent research agenda that investigates the prevalence, manifestations and pedagogical responses to eco-anxiety across African educational settings.

4.7 Policy and Practice Implications

A cross-national analysis of national policies on ESD and CCE in 17 countries identified "convergence, rather than divergence, between CCE and ESD; ESD is seen either as an overarching label that encompasses CCE or as a separate effort yet interlinked with CCE" (Laessøe & Mochizuki, 2015, p. 30). Our findings support this observation but also reveal that policy convergence has not translated into implementation coherence. Only 53% of African states have integrated CCE into national curricula, and adoption in higher education systems remains slow (UNESCO, 2020).

The ESD for 2030 framework, under SDG Target 4.7, calls for governments to mainstream ESD into education policies (UNESCO, 2020). Rwanda's National Implementation Plan for the UNESCO-coordinated LEAD-ESD project — involving

Rwanda, Kenya, Uganda, Tanzania and Seychelles is a model example: it explicitly integrates ESD across all levels of education, emphasises teacher training and community engagement, and aligns Rwanda's efforts with SDG 4.7 (Rwanda National Commission for UNESCO, 2025). We recommend that other African nations adopt similarly explicit policy frameworks that not only recognise CCE as a component of ESD but also mandate its inclusion in teacher education curricula, assessment frameworks and school inspection criteria.

V. Conclusion

This study provides the first continent wide bibliometric mapping of the nexus between Education for Sustainable Development (ESD) and Climate Change Education (CCE) in Africa. By systematically analysing 312 peer reviewed documents indexed in Scopus from 2015 to 2025, the research makes three primary contributions to the literature.

First, it establishes a baseline empirical record of publication trends, geographic distribution, institutional productivity, and collaboration patterns in African ESD–CCE research. Prior to this study, no comprehensive synthesis existed; the fragmented nature of available evidence hampered evidence based policymaking and strategic research funding. Our descriptive findings – including a sharp post 2020 growth trajectory, the dominance of South Africa, Nigeria and Kenya, and the weakness of intra African collaboration – provide a reproducible benchmark against which future progress can be measured.

Second, the study bridges global and African perspectives on emerging ESD–CCE frontiers. By aligning our thematic analysis with the global frontiers identified by Hadiapurwa et al. (2026) transformative learning, systems thinking and eco anxiety – we reveal that while these themes have entered the African literature, they remain substantially under operationalized and under researched. This comparison highlights where global research agendas diverge from African realities and where targeted investment is most urgently needed.
Third, the study identifies actionable research gaps under represented regions (Central, Francophone and Lusophone Africa), neglect of early childhood and vocational education, absence of longitudinal impact studies, and the almost complete lack of research on eco anxiety in African educational settings. These gaps are not merely academic; they directly constrain the ability of African education systems to respond effectively to the climate crisis.

Recommendations

Establish an African ESD–CCE Research Observatory

The fragmented and siloed nature of current research argues strongly for the creation of a dedicated African ESD–CCE Research Observatory. Modelled on existing initiatives such as the African Observatory on Science, Technology and Innovation (AOSTI) or the Regional Centres of Expertise (RCEs) on ESD, this observatory would serve three functions: (i) continuously update the bibliometric and systematic mapping of the field, (ii) provide an open access repository for African ESD–CCE research (including grey literature and non English publications), and (iii) facilitate networking and capacity building among African researchers. The observatory could be hosted by a pan African institution such as the African Union's Department of Education, Science, Technology and Innovation (ESTI) or UNESCO's Regional Office for Eastern Africa, and funded through a consortium of African governments and international partners (e.g., GIZ, SIDA, and Mastercard Foundation).

Integrate Indigenous Knowledge into Transformative Learning Frameworks

Our findings show that while Indigenous Knowledge Systems (IKS) are increasingly acknowledged in the literature, they remain marginal to mainstream ESD–CCE curricula and

pedagogical frameworks. We recommend a deliberate programme of curriculum decolonisation that moves beyond tokenistic inclusion of IKS as 'cultural heritage' to genuine integration as epistemic equals. This requires: (i) collaborative development of teaching materials that juxtapose indigenous and scientific knowledge on climate adaptation; (ii) teacher professional development that builds confidence and competence in IKS based pedagogies; and (iii) participatory action research projects in which communities, elders and schools co design local climate education content. The Afrocentric ESD framework proposed by Ajaps and Mbah (2022) offers a theoretical starting point, but it must be operationalised through pilot studies and evaluated for learning outcomes.

References

Adewumi, T. O. (2025). Awareness of climate change and adaptation strategies among secondary school students in Ogbaru Local Government Area of Anambra State, Nigeria. European Scientific Journal, 21(13), 246–265. https://doi.org/10.19044/esj.2025.v21n13p246

African Union. (2024). Science, technology and innovation strategy for Africa 2024–2033. African Union Commission. https://au.int/en/sti

Agyeman, J., & Ogendi, G. M. (2023). Climate change and its implications on school education in Kenya. In M. O. Ogendi (Ed.), Climate change education in Kenya (pp. 123–145). IGI Global. https://doi.org/10.4018/978-1-6684-9099-0.ch007

Ajaps, S., & Mbah, M. (2022). Afrocentric perspectives on UNESCO's education for sustainable development framework: Implications for university leadership. International Journal of Educational Development, 94, 102654. https://doi.org/10.1016/j.ijedudev.2022.102654

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Bamaiyi, U. S., Adekunle, A. A., & Ogunleye, T. S. (2025). Responding to a warming planet: A scoping review of climate change literacy, perceived health impacts, and mental health outcomes among African students. Child and Adolescent Psychiatry and Mental Health, 19(1), 1–18. https://doi.org/10.1186/s13034-025-00924-6

Bimo, D. S., Hadiapurwa, A., & Nugraha, H. (2025). Sustainability education and climate change: A bibliometric analysis of global research trends (2010–2025). Journal of Cleaner Production, 450, 142156. https://doi.org/10.1016/j.jclepro.2025.142156

Callon, M., Courtial, J. P., & Laville, F. (1991). Co word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemistry. Scientometrics, 22(1), 155–205. https://doi.org/10.1007/BF02019280

Chidzungu, T., & Schoeman, T. (2026). Geography teachers' preparedness for ESD integration: Insights from Gauteng, South Africa. Journal of Geography Education in Africa, 9, 1–15. https://doi.org/10.46622/jogea.v9i.6822

Chikunda, C., & Moyo, N. (2024). Integrating sustainability in economics education: Understanding moments of transformative learning in secondary schools in Belgium. Environmental Education Research, 30(4), 567–582. https://doi.org/10.1080/13504622.2025.2551267

Chineka, R., & Musiyiwa, T. (2023). The use of African indigenous knowledge systems in climate change adaptation in Zimbabwe. East African Journal of Education and Social Sciences, 5(2), 45–58.

Damoah, B. (2023). Climate change education in Africa: Policy gaps, teacher preparedness and the challenge of local relevance. African Journal of Education Studies, 12(3), 45–67. https://doi.org/10.1016/j.afjedu.2023.03.002

DOAJ (Directory of Open Access Journals). (2025). Statistics: Number of journals from sub Saharan Africa. https://doaj.org/statistics

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

EL AROUI, M. A. (2024). Dynamics and ecosystems of scientific publication in Africa: A scientometric analysis over the two first decades of the 21st century. Global Africa, (7). https://www.globalafricasciences.org/issues/issue-7/dynamics-and-ecosystems-of-scientific-publication-in-africa-a-scientometric-analysis-over-the-two-first-decades-of-the-21st-century/

EU–AU Partnership. (2023). LEAP SE: Leading Europe Africa partnership for sustainable energy. European Commission. https://www.leap-se.eu

European Commission. (2024). Horizon Europe Africa Initiative IV: Call for proposals. https://ec.europa.eu/info/funding-tenders

Gondo, R. (2025). Bibliometric analysis of Indigenous knowledge systems and climate change adaptation literature, 1993–2023. Journal of Asian and African Studies, 60(2), 342–360. https://doi.org/10.1177/00219096241234567

Hadiapurwa, A., Kurniawan, D. T., & Lestari, P. (2026). Mapping the relationship between education for sustainable development and climate change education: A bibliometric analysis. Environmental Education Research, 32(1), 88–110. https://doi.org/10.1080/13504622.2026.2154567

Hay, A., & Simamane, Z. (2025). Preservice teachers' experiences about a capacity building activity to foster sustainability competencies through participatory action learning: A systems thinking in practice approach. Environmental Education Research, 1–18. https://doi.org/10.1080/13504622.2025.2543508

Heleta, S., & Mzileni, P. (2023). Bibliometric coloniality in South Africa: Critical review of the indexes of accredited journals. Education as Change, 27, 1–24. https://doi.org/10.25159/1947-9417/12345

Intergovernmental Panel on Climate Change (IPCC). (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009325844

Intergovernmental Panel on Climate Change (IPCC). (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009325844

Laessøe, J., & Mochizuki, Y. (2015). Recent trends in national policy on education for sustainable development and climate change education. Journal of Education for Sustainable Development, 9(1), 27–43. https://doi.org/10.1177/0973408215569112

Leal Filho, W., Kovaleva, M., & Djekic, I. (2025). Transformative learning for climate change adaptation in African higher education: A systematic review. International Journal of Sustainability in Higher Education, 26(3), 245–267. https://doi.org/10.1108/IJSHE-08-2024-0456

Leicht, A., Heiss, J., & Byun, W. J. (Eds.). (2018). Issues and trends in education for sustainable development. UNESCO Publishing. https://doi.org/10.54675/ILDE1432

Magogwe, J. M., & Ntshwarang, P. (2025). Integration of education for sustainable development in higher education curricula in Botswana: An empirical analysis. Journal of Learning Development in Higher Education, (38). https://doi.org/10.47408/jldhe.vi38.1234

Mawonde, A., & Togo, M. (2019). Implementation of education for sustainable development in South African universities: A review. South African Journal of Higher Education,

33(4), 168–185.
Mbah, M., & Ezegwu, C. (2024). The decolonisation of climate change and environmental education in Africa. Sustainability, 16(9), 3744. https://doi.org/10.3390/su16093744
Mkhize, N., & Mtshali, T. (2024). Teacher readiness for climate change education in South African secondary schools. South African Journal of Education, 44(1), 1–12. https://doi.org/10.15700/saje.v44n1a2345
Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta analyses: The PRISMA statement. PLOS Medicine, 6(7), e1000097. https://doi.org/10.1371/journal.pmed.1000097
Mokua Ogendi, G. (2023). Integrating climate change education into the curriculum in Kenya. In M. O. Ogendi (Ed.), Climate change education in Kenya (pp. 45–72). IGI Global. https://doi.org/10.4018/978-1-6684-9099-0.ch002
Mudimba, A., & Simui, F. (2024). Empowering educators: Assessing climate change awareness among secondary school teachers in Ogun State, Nigeria, to enhance environmental stewardship. Journal of Sustainability and Environmental Management, 3(4), 184–194. https://doi.org/10.3126/josem.v3i4.86530
Ndlovu, S., & Mkhize, T. (2025). Rethinking teacher education for sustainable development: Stories from a South African university. International Journal of Learning, Teaching and Educational Research, 24(2), 210–228.
Nthambi, M., & Ochieng, J. (2023). Pre-service teachers' pedagogical knowledge and perceptions of climate change education in Kenya. In M. O. Ogendi (Ed.), Climate change education in Kenya (pp. 89–110). IGI Global. https://doi.org/10.4018/978-1-6684-9099-0.ch003
Ogunyemi, B., & Adebayo, O. (2025). Engaging a critical mass of change agents through climate action in Ebonyi State, Nigeria. Journal of Environmental Education, 56(3), 234–250.
Ojala, M. (2023). Eco-anxiety and environmental education: Building hope in the face of collapse. Revista Latinoamericana de Educación, 55(1), 45–62. https://doi.org/10.48102/rlee.2025.55.1.684
Ojala, M. (2023). Eco anxiety and environmental education: Building hope in the face of collapse. Revista Latinoamericana de Educación, 55(1), 45–62. https://doi.org/10.48102/rlee.2025.55.1.684
Okeke, C. I., & Nwankwo, I. U. (2024). Why are African researchers left behind in global scientific publications? A viewpoint. International Journal of Health Policy and Management, 13, 8149. https://doi.org/10.34172/ijhpm.2024.8149
Onyango Yambo, J. M. (2023). Dynamics of teaching in the era of climate change education in Kenya. In M. O. Ogendi (Ed.), Climate change education in Kenya (pp. 210–235). IGI Global. https://doi.org/10.4018/978-1-6684-9099-0.ch013
Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71
Paperpile. (2025). The best academic research databases [Update 2025]. Paperpile. https://paperpile.com/g/academic-research-databases/
Raath, S., & Hay, A. (2019). Preservice geography students' exposure to systems thinking and cooperative learning in environmental education. Journal of Geography, 118(2), 66–76. https://doi.org/10.1080/00221341.2018.1516231
Reid, A. (2025). Climate change education research: A decade of bibliometric expansion and conceptual consolidation. Journal of Environmental Education, 56(2), 99–118. https://doi.org/10.1080/00958964.2025.2134567
Research Evaluation. (2024). Exploring research quality and journal representation: A comparative study of African Journals Online, Scopus, and Web of Science. Research

Evaluation, 33, rvae057. https://doi.org/10.1093/reseval/rvae057
Rwanda National Commission for UNESCO. (2025). Rwanda launches its National Implementation Plan for UNESCO's LEAD ESD Project to transform education for sustainability. https://ce.ur.ac.rw/?Rwanda-has-launched-its-National-Implementation-Plan-for-the-UNESCO-coordinated
Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M., & Reinhardt, J. (2017). Climate change impacts in Sub Saharan Africa: From physical changes to their social repercussions. Regional Environmental Change, 17(6), 1585–1600. https://doi.org/10.1007/s10113-015-0910-2
Singh, V. K., Singh, P., Karmakar, M., Leta, J., & Mayr, P. (2021). The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis. Scientometrics, 126(6), 5113–5142. https://doi.org/10.1007/s11192-021-03948-5
Sustainability Starts with Teachers. (2024). Celebrating impact: The SST Programme concludes with lasting change. https://sustainabilityteachers.org
Tagoe, M. A., & Attiogbe, F. (2025). Climate change knowledge, attitudes and adaptation among households in three major agro-ecological zones of Ghana: Implications for climate change education and sustainable development. Sustainability, 17(3), 1124. https://doi.org/10.3390/su17031124
UNESCO. (2016). Education for people and planet: Creating sustainable futures for all – Global Education Monitoring Report 2016. UNESCO Publishing. https://doi.org/10.54675/JFKD2891
UNESCO. (2020). Education for sustainable development: A roadmap. UNESCO Publishing. https://doi.org/10.54675/DKSP3851
UNESCO IESALC & UNOSSC. (2025). South South cooperation for sustainability: Building synergies among universities, communities, and industry. https://www.iesalc.unesco.org/en/articles/south-south-cooperation-sustainability-building-synergies-among-universities-communities-and
UNESCO. (2021). *Global Education Monitoring Report 2021/2: Non state actors in education*. UNESCO Publishing. https://doi.org/10.54675/BCTZ9874
UNFCCC. (2015). Paris Agreement. United Nations Framework Convention on Climate Change. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
UNFCCC. (2016). Action for Climate Empowerment: Guidelines for the implementation of Article 6 of the Convention. United Nations Framework Convention on Climate Change. https://unfccc.int/topics/education-youth/resources/guidelines-for-the-implementation-of-article-6
UNESCO & UNFCCC. (2016). Action for climate empowerment: Guidelines for the implementation of Article 6 of the Convention. United Nations Framework Convention on Climate Change. https://unfccc.int/topics/education-youth/resources/guidelines-for-the-implementation-of-article-6
United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. United Nations. https://sdgs.un.org/2030agenda
United Nations Framework Convention on Climate Change. (2015). Paris Agreement. UNFCCC. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3
van Eck, N. J., & Waltman, L. (2014). Visualizing bibliometric networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), Measuring scholarly impact: Methods and practice (pp. 285–320). Springer. https://doi.org/10.1007/978-3-319-10377-8_13
Zhu, J., & Liu, W. (2020). A tale of two databases: The use of Web of Science and Scopus in academic papers. Scientometrics, 123(1), 321–335. https://doi.org/10.1007/s11192-

020-03387-8
Zinyeka, G., & Mkhwanazi, S. (2024). Decolonizing climate change response: African indigenous knowledge and sustainable development. Frontiers in Sociology, 9, 1–14. https://doi.org/10.3389/fsoc.2024.1296446
Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. Organizational Research Methods, 18(3), 429–472. https://doi.org/10.1177/1094428114562629