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Research Article

Research Productivity and Impact on Sustainability in Higher Education Institutions: A Bibliometric Review

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ABSTRACT

Sustainable Higher Education has been getting more and more attention from experts, students, and academic organizations around the world over the past 25 years. This bibliometric study looks at 365 articles in Scopus that are about higher education for sustainable development. The review's goals were to show the amount of literature, its growth trends, and where it was found geographically. It was also meant to find important writers, journals, and articles, look into the intellectual structure of the field, and bring attention to new areas of research. Findings show a body of work that is growing quickly and isn't very old. Most of it was written by experts in wealthy countries. There are four main magazines in the field, which can be told apart by the number of articles they publish and the number of times they are cited. The study of author co-citations found three main thematic clusters: managing sustainability in higher education, skills related to sustainability, and strategies for application. This review sets a basic standard for future research in Sustainable Higher Education. It also shows how the field's intellectual world is changing and gives new researchers important entry points.

Keywords: Higher Education; Sustainability; Sustainable Development; Bibliometric Review; Systematic Review; University; Education For Sustainable Development.

1. Introduction

In the 1990s, educators expressed concerns regarding the inefficient use of resources and the adverse effects of economic development on the environment, thereby elevating the significance of 'environmental education' (Jickling et.al., 2012). This served as the precursor to what is now referred to as 'education for sustainable development' (Aikens et.al., 2016). Over the last twenty years, the international policy community has intensified efforts to enhance awareness and incorporate education into global policy initiatives focused on sustainable development (Jickling et.al., 2012). The initiation of the United Nations 'Decade of Education for Sustainable Development' in 2004 sought to incorporate the values, principles, and practices of sustainable development into both formal and informal educational frameworks. This belief is based on the premise that education facilitates the development of the knowledge and attitudes essential for citizens in all nations to establish sustainable societies (Aikens et.al., 2016).

In 2015, following the Decade of Education for Sustainable Development, the United Nations adopted 17 sustainable development goals signifying an expansion of global initiatives aimed at fostering sustainable societies. The Sustainable Development Goals established the objective of ensuring that all children have access to quality education that fosters lifelong learning. Several scholars and policymakers contend that education for sustainable development constitutes the most essential of the 17 Sustainable Development Goals (SDGs). Education that fosters sustainable values, attitudes, and behaviors in the next generation of global citizens is essential for achieving all Sustainable Development Goals (SDGs).

The perspectives regarding the aims and significance of education for sustainable development are applicable to primary, secondary, and tertiary education. Tertiary education offers distinct contributions that set its role in education for sustainable development apart from education. Higher education institutions are tasked

with equipping primary and secondary school teachers with the necessary knowledge, skills, and attitudes for effective sustainability education. The curricula across various university disciplines serve as mechanisms for equipping higher education students with the skills to adopt sustainable attitudes and practices in their lives (Figueiró et.al., 2015). The role of universities in knowledge creation has significant implications for global efforts to identify sustainability solutions. The identified features indicate that higher education for sustainable development can be effectively analyzed as a hybrid within the larger context of education for sustainable development (Lozano, et.al., 2013; Stephens et.al., 2008.). Colleagues characterized higher education for sustainable development as educational cultures that facilitate individuals in reflecting on their responsibilities regarding the complex consequences of decision-making and behavior through multicultural, global, and future-oriented perspectives (Adomßent,et.al., 2014).

This bibliometric study aims to build on previous evaluations by charting the growth of sustainable development education at the university level from its start in the late 90s all the way up to 2018. This evaluation was based on many research questions.

RQ1: How many documents are there in the Sustainable Higher Education knowledge base, how fast are they growing, and how are they distributed among nations, paper types, and research methodologies?

RQ2: Who have been the most influential publications, writers, and research articles in the field of Sustainable Higher Education?

RQ43: How is the body of information that supports Sustainable Higher Education theory and research organized intellectually?

RQ4: What have been the most popular or "research front" subjects in Sustainable Higher Education studies recently?

Journal articles, books, and book chapters made up 1459 of the documents indexed by Scopus in this database that this review uncovered. The bibliographic data linked to these papers was examined with the use of Excel, Tableau, VOSviewer, and Scopus analytical tools. Metadata analysis, social network analysis, keyword co-occurrence analysis, direct citation analysis, and descriptive statistics were all part of the data analysis process (Zupic et.al., 2015).

Previous reviews of research have looked at the Sustainable Higher Education knowledge base from several angles, such as implementation hurdles (Sipos, et. al., 2008), teacher education (Velazquez et al., 2006), teaching and learning (Ferreira et al., 2009), and conceptual models (Breßler et al., 2017),. This study aims to add to those studies. In addition to what was said before, this study aims to expand upon the results that colleagues presented in their bibliometric analysis of Sustainable Higher Education studies (Ávila, et al., 2018).

2. Materials and Methods:

Research on sustainable development in higher education was reviewed using bibliometric approaches in this scientific mapping assessment of the literature. The actual results of studies are not considered in research reviews based on bibliometric methodologies. Their true worth lies in their capacity to record and combine overarching tendencies that characterize the make-up, organization, and conceptual framework of a body of information.

As a result, science mapping provides a picture of knowledge accumulation patterns that are hard to "see" when utilizing conventional research evaluation techniques (Zupic et.al., 2015).

3. Identification of Sources

Scopus was the first library that was searched to find a large group of papers that would be good for bibliometric analysis. Researchers first found 991 records using carefully picked keywords. There were a lot of different kinds of books in this first collection, but it was clear that not all of them would meet the specific criteria needed for a useful analysis.

The first step toward improvement was to use a timeline filter to only look at articles from 1999 to 2023. With this small change, a few papers were left out, lowering the number to 907. Even though it was a small cut, it made sure that only the newest and most important research was looked at. The next thing that was looked at was the subjects. It was only works in the Social Sciences, Business & Management, and Multidisciplinary studies that the researchers looked at. With this theme-based filter, the documents were narrowed down to 501 papers that were directly relevant to the study goals.

The team then chose only articles and review papers because they knew that the types of documents should be consistent. These kinds of papers are great for bibliometric analysis because they usually contain original research or thorough descriptions of what is already known. Because of this, the collection was cut down even more, to 440 papers. In order to get closer to the ideal set, the researchers made sure that only papers that were almost ready to be published were included. This filter was very important for keeping the analysis's quality and reliability. It left 380 papers in the pool.

The next step was to pay attention to the source type. Only journal papers were kept because they are usually more reliable and go through a strict peer-review process. With this smart move, the number of documents

reached 370. Then, uniformity in language was given the most attention so that there would be no problems with analysis and understanding. Only papers written in English were chosen, and the final, improved collection has 365 documents. Once all the papers had been carefully checked and made eligible through several stages, 365 were found to meet all the requirements. The next bibliometric analysis was built around these papers, which gave a solid, high-quality look into the chosen areas of study. The researchers made sure that the integrity, relevance, and quality of the information were not affected at any point, from the first recognition to the final pick. This process shows how important it is to use a planned and organized method when doing bibliometric studies, as the accuracy of the choices made has a direct effect on the truth and usefulness of the results.

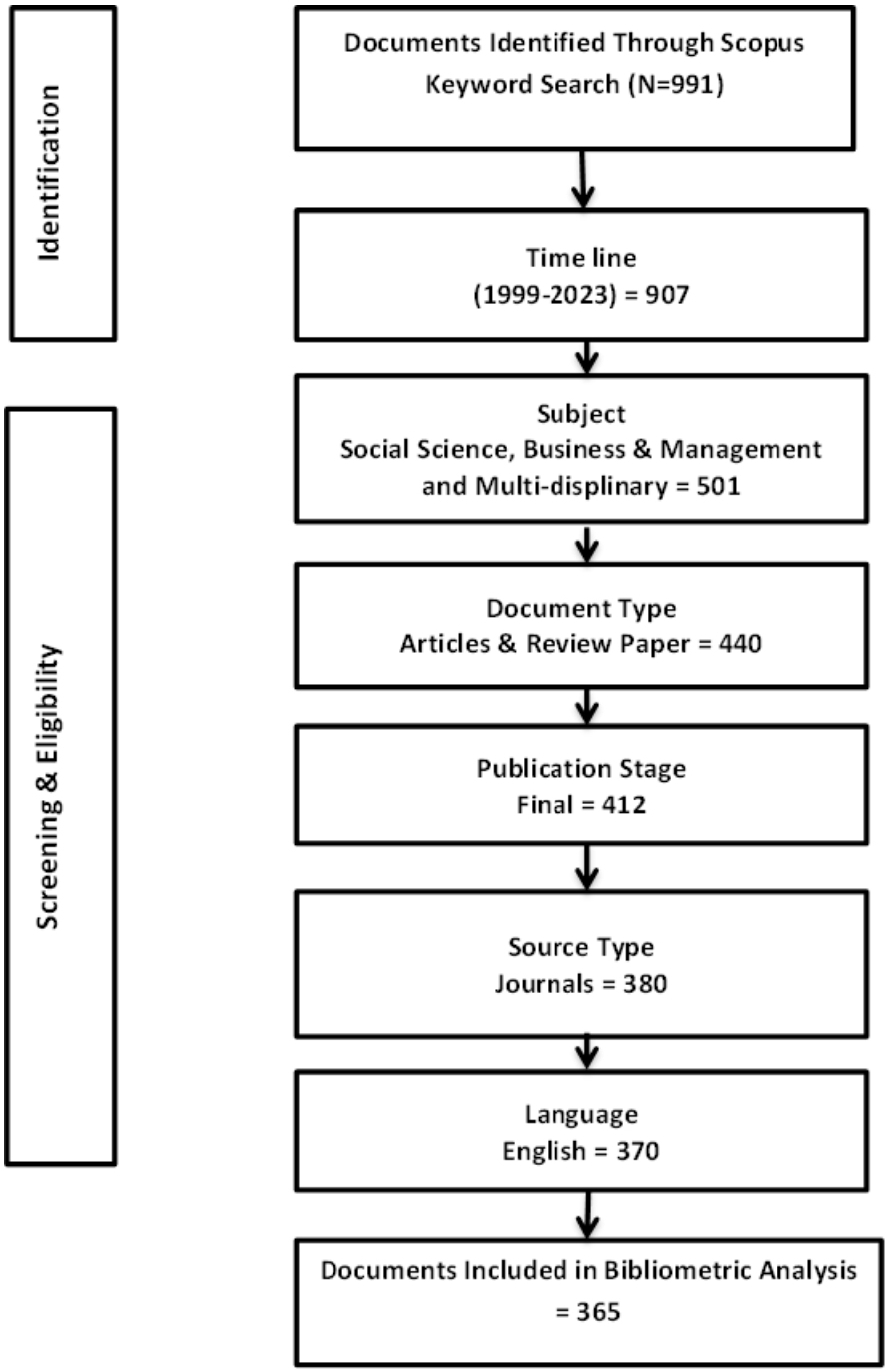

Fig 1: The bibliometric analysis procedure

4. Data Extraction and Analysis

An Excel file contained bibliographic data on the 365 documents' pertinent aspects. Each article's Meta data—author names, affiliations, title, source, reference, keywords, abstracts, and citation data—was in the file. For VOSviewer analysis, we created a thesaurus file to filter data [30]. Thesaurus files improve bibliometric review accuracy (Van Eck et al., 2009). Quantitative data analysis used descriptive statistics,

citation, co-citation, and social network analysis. The knowledge base's size, development trajectory, geographical distribution, paper type, and research methodologies were described using descriptive statistics. The descriptive analyses were done using Scopus, Tableau, and MS Excel.

Bibliometric analysis uses 'direct citation' and 'co-citation' studies for different objectives. From the Sustainable Higher Education knowledge repository, direct citation analysis identified important authors, publications, and journals. Direct citation analysis counts the number of Scopus index citations of the 445 Sustainable Higher Education publications in the review database. This review uses 'Scopus citations' from direct citation analysis. If the review included materials from Web of Science or Google Scholar, the citation findings would change since these databases have different numbers of documents. Citation analyses using these indices give a certain amount of 'Web of Science citations' or 'Google Scholar citations'. Citation analysis and co-citation analysis provide complimentary insights into scholarly impact. Co-citation, described by Zupic and ˇCate (2015) is the frequency of two units (authors, documents, journals) being referenced jointly. The software application produces a matrix using the review database's 445 papers' "reference lists" in co-citation analysis. There are three types of co-citation analysis: journal, author, and document. Each analyzes co-citation frequency matrices.

Co-citation analysis collects a considerably bigger literature since it uses reference lists rather than review documents. Co-citation analysis can include papers outside the review database and Scopus, giving it a broader picture of academic influence than direct citation analysis Zupic and ˇCate (2015). Co-citation analysis enhances direct citation analysis. In addition to total co-citations, co-citation analysis generates 'measures of similarity' between documents, authors, or journals. Co-citation analysis may graphically show the link between writers in a field based on other researchers' co-citations. In this evaluation, VOSviewer software was used to build 'social network maps' of document characteristics in Sustainable Higher Education knowledge base (Van Eck et al., 2009). Co-citation maps may assess knowledge base relationship properties. Author co-citation maps can indicate a knowledge base's "intellectual structure" by analyzing author similarities in the literature (Van Eck et al., 2009). Keyword co-occurrence analysis or 'co-word analysis' was used to emphasize the subject makeup of the Sustainable Higher Education knowledge base for the final study question (Van Eck et al., 2009). Co-word analysis counts the amount of times two keywords co-occur in the title, abstract, or keyword list of review database records (Van Eck et al., 2009). Co-word analysis may discover frequently recurring keywords in documents and illustrate their relationship in a network map (Van Eck et al., 2009).

5. Results

The presentation of results is aligned to the four research questions.

Volume, Growth Trajectory, and Distribution of the Sustainable Higher Education Literature

The 365 Sustainable Higher Education papers found in the Scopus search were all journal articles. This confirms that since the first paper on this subject in 1999 (Johnson et al., 1998), a significant amount of publications has surfaced. Longitudinal study of the database indicates three general phases of evolution for the Sustainable Higher Education knowledge base (see Figure 2).

- 1999 to 2016, the emergent growth period;
- 2017 to 2019, the steady growth stage;
- 2019 to 2023, the accelerating growth stage.

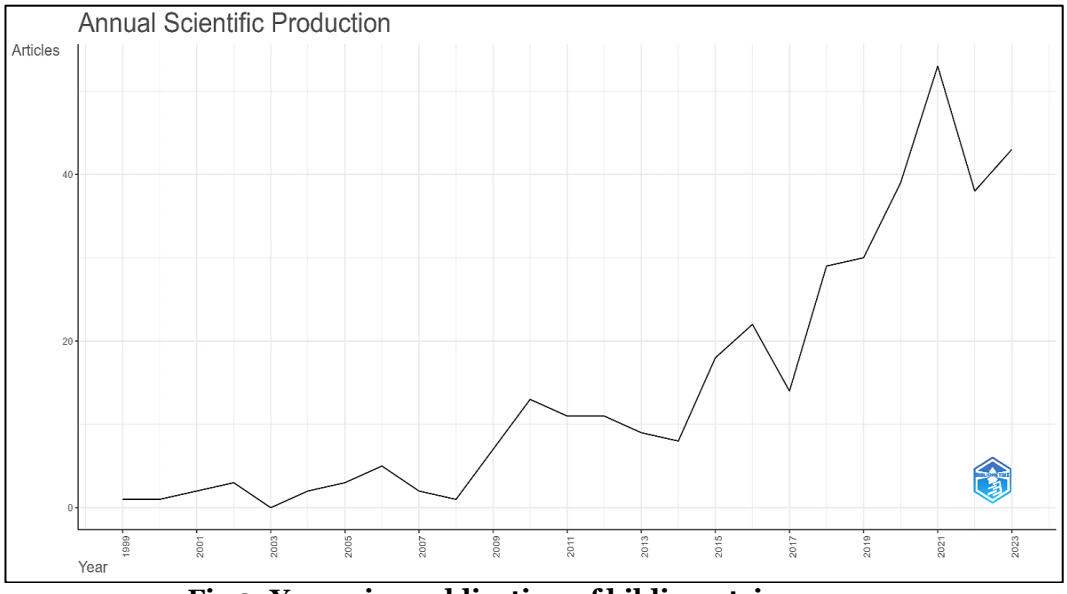

Fig 2: Year wise publication of bibliometric papers

These longitudinal studies show that 64% of the HESCD literature has been generated within the last seven years since 2019. These patterns validate the HESD literature's recent age and growing appeal among academics.

Table 1: Keywords

S.No.	Keyword	Occurrences	Total Link Strength
1.	Sustainability	332	1147
2.	Education	162	588
3.	Sustainable Development	127	523
4.	Higher Education	111	421
5.	Education Policy	88	303
6.	Policy Making	70	282
7.	Environmental Education	56	203
8.	Policy	42	143
9.	Learning	40	206
10.	Curriculum	38	177
11.	Student	38	192
12.	University Sector	38	180
13.	Teaching	37	181
14.	Article	33	151
15.	Educational Development	33	157
16.	Policy Implementation	33	147
17.	Climate Change	30	136
18.	Human	27	121
19.	Policy Approach	27	124
20.	Environmental Policy	25	111

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Table 1 the keyword co-occurrence data reveals the core thematic structure and topical emphasis within the Sustainable Higher Education research landscape. The analysis is based on keyword frequency (**occurrences**) and the degree to which each keyword is connected with others (**total link strength**), indicating how central a term is in the broader knowledge network. "Sustainability" (Occurrences: 332 & Link Strength: 1147) is by far the most dominant keyword, underscoring the central focus of the literature. Its exceptionally high total link strength suggests strong and consistent integration with other topics, confirming its position as the conceptual anchor of Sustainable Higher Education research. "Education" (Occurrences: 162 & Link Strength: 588) and "Sustainable Development" (127/523) follow closely, revealing the foundational pillars of the discourse. Together, these three terms highlight the field's dual concern with both educational processes and sustainability goals. "Higher Education" (111/421) reinforces the specific institutional context under investigation, aligning with the field's aim to explore the roles, responsibilities, and transformative potential of universities in sustainability initiatives. "Education Policy" (88/303) "Policy Making" (70/282) "Policy" (42/143) "Policy Implementation" (33/147) "Policy Approach" (27/124) "Environmental Policy" (25/111). These keywords indicate a strong focus on how policy frameworks shape, enable, or limit sustainable practices within educational institutions. The high total link strengths suggest these topics are often discussed in conjunction with others like curriculum, institutional change, and government agendas. "Curriculum" (38/177), "Teaching" (37/181), "Learning" (40/206), and "Educational Development" (33/157) reveal that much of the Sustainable Higher Education literature is dedicated to understanding how sustainability is embedded in teaching and learning processes.

The relatively even distribution of these keywords in both frequency and link strength suggests a mature and balanced discourse on the pedagogical approaches to integrating sustainability in higher education. "Student" (38/192) and "University Sector" (38/180) indicate that research is paying attention not only to systemic and curricular dimensions but also to the roles of key actors. The recurrence of these keywords highlights the importance of stakeholder involvement and institutional commitment in advancing sustainability agendas. "Climate Change" (30/136) is a significant issue intersecting with Sustainable Higher Education, though its slightly lower link strength compared to pedagogical and policy-related terms suggests that it is emerging but not yet fully central in the core dialogue. "Human" (27/121) point to the inclusion of humanistic and anthropocentric themes—possibly ethics, values, and social dimensions—which are critical to advancing holistic sustainability education. "Article" (33/151), though less conceptual, likely refer to metadata tags or methodological descriptors used during indexing. Their presence here suggests an awareness of document types and possibly methodological reflections in the research.

Sustainability, education, and policy are the most central themes in HESD literature. There is robust interest in rethinking curriculum, pedagogy, and institutional practices. A significant portion of the research focuses on how policies affect the implementation of sustainability in higher education. Climate change and human-centered aspects are gaining traction but are not yet dominant. Balanced discourse: The keyword spread shows a relatively well-developed field with interlinked themes across conceptual, operational, and actor-based dimensions.

Although contributions to the Sustainable Higher Education literature have come from scholars located in 100 different countries, there is a noticeable geographical imbalance in this knowledge base (see Figure 3). Most Sustainable Higher Education studies have been authored by scholars located in relatively few societies. More specifically, scholars from the United States (USA), United Kingdom (UK), Australia, and China have produced 55% of the Sustainable Higher Education literature.

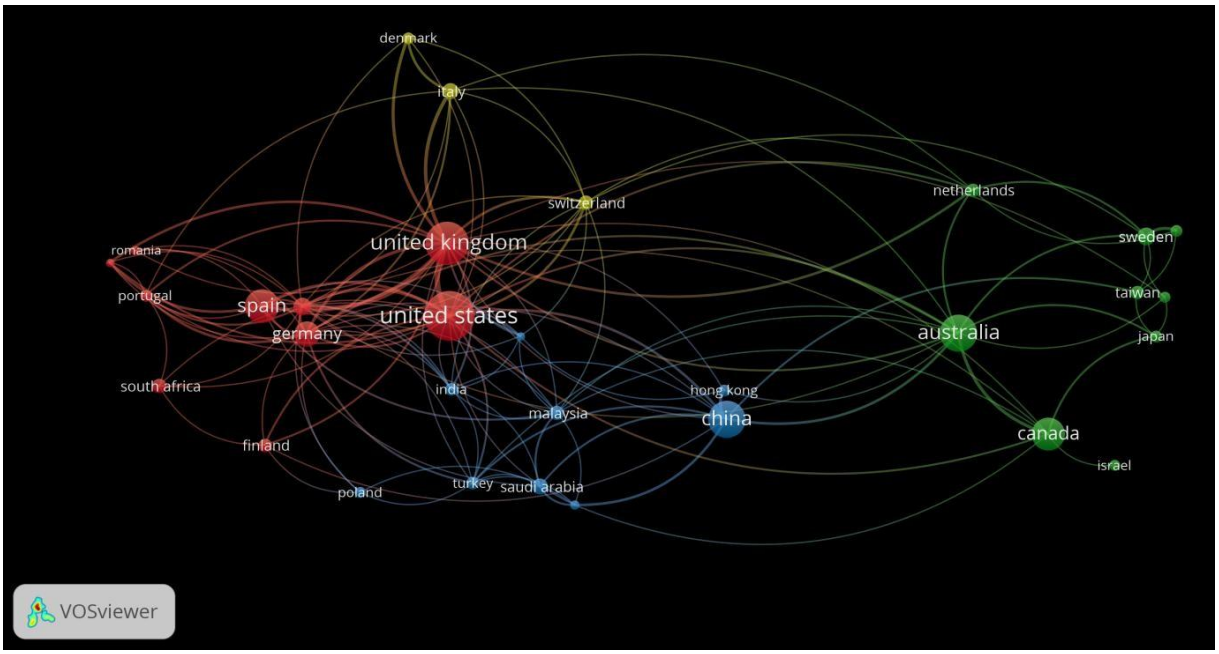

Fig 3: Research paper countries wise

Drilling down further, it was observed that 73% of the documents in the Sustainable Higher Education database came from Top 20 Countries, and only 27% from rest of the countries. While this may be unremarkable in terms of comparison with publication trends in other disciplines, it is potentially problematic in a field such as Sustainable Higher Education where implementation solutions may not always transfer readily. While this suggests a positive trend, the numerous 'blank spots' on the heat map which almost entirely comprise developing societies cannot be ignored (see Figure 3).

6. Influential Journals, Authors, and Documents:

The second research question sought first to understand how contributions to the Sustainable Higher Education knowledge base were distributed across journals, and then to identify influential authors and documents. The 445 journal articles included in the review database were published in 152 different journals. Figure 4 showing Journals citations and overall link strength reveals the main publications shaping the research environment. Leading the pack is Sustainability (Switzerland), which has 3,261 citations and total link strength of 169 rules. This suggests not just great awareness but also close ties to other media, so highlighting its key and powerful influence in the sector. Though having less networking than Sustainability (Switzerland), the Journal of Cleaner Production stands out with 1,647 citations and modest link strength of 28, verifying its relevance in environmental and sustainability research.

Though it might be mentioned less often than the top sources, Environmental Education studies maintains important cooperative or thematic ties with other studies, as seen by its comparatively low 363 citations but high link strength of 79. Though they are acknowledged as influential sources, some renowned journals such Global Environmental Change (348 citations), Science (340 citations), and Social Science and Medicine (196 citations) have no total link strength, indicating they are not very networked within the particular dataset examined. Other specialized journals like Technological Forecasting and Social Change (284 citations) and Sustainable Development (238 citations) also add significantly, with Sustainable Development displaying a fair link strength of 27, therefore emphasizing its connectedness in the literature network.

Journals with an educational emphasis, including the International Journal of Sustainability in Higher Education (235 citations) and the Journal of Environmental Studies and Sciences (207 citations), indicate the incorporation of sustainability ideas into education research. At the same time, specialty publications like

Environmental Science and Policy (97 citations, 19 link strength) and Environment, Development and Sustainability (167 citations, 40 link strength) are becoming more significant venues mixing sustainability and policy-oriented debates.

Journals like Marine Policy (94 citations), Technology in Society (76 citations), and Australian Journal of Environmental Education (67 citations) are lower in citation counts but still influential in niche areas, reflecting their specialized but vital contributions and maintaining reasonable link strengths. Though they exhibit lesser link strengths in this particular theme network, a few high-profile multidisciplinary publications including PLOS ONE (78 citations) and Proceedings of the National Academy of Sciences of the United States of America (44 citations) are also included. With Sustainability (Switzerland) at the center, the bibliometric mapping shows a varied and interconnected field surrounded by both highly cited general science journals and more specialized publications that, while they may have less citations, play important bridging roles in the academic conversation around sustainability, environment, and education.

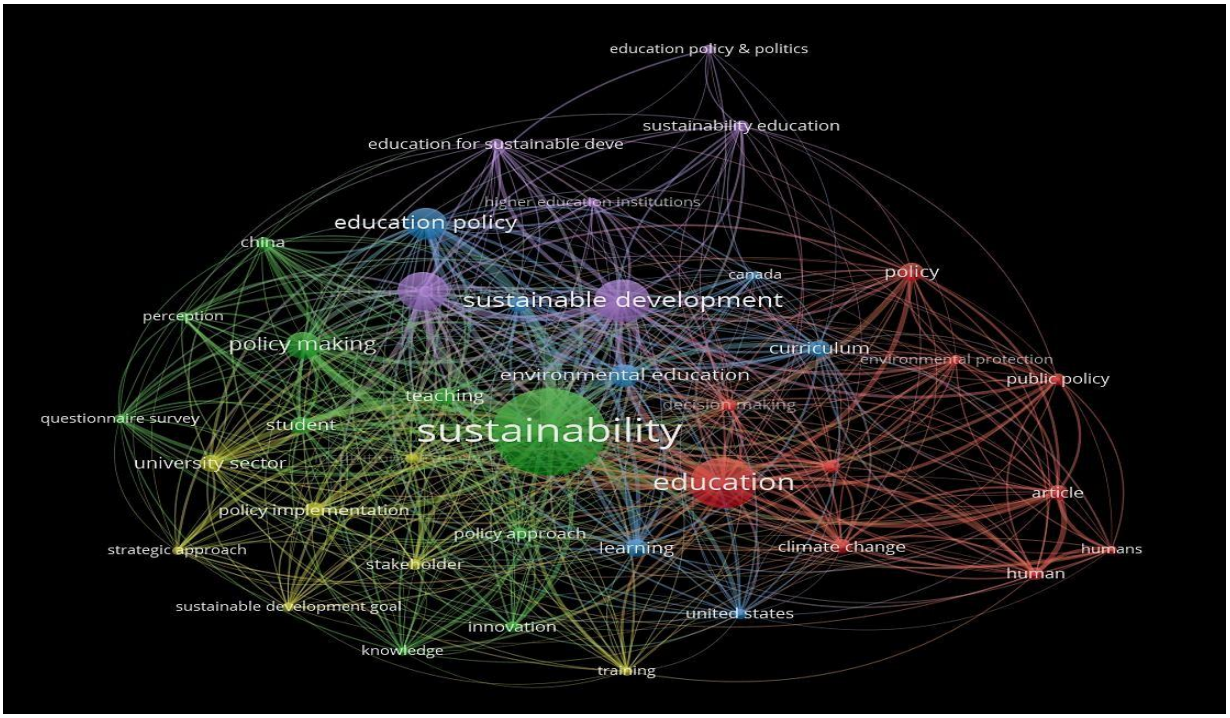

Fig4: Keyword occurrence

6.1 Journals:

On the positive side, this pattern of broad dispersion suggests that interest in Sustainable Higher Education is not limited to a few 'specialty journals'. This was affirmed by analysis of the topical foci of journals publishing Sustainable Higher Education research. Specifically, the range of journals publishing articles about Sustainable Higher Education included journals specializing in education, higher education, education policy, educational administration, geography, science, the environment, engineering, energy, chemistry, construction, architecture, development, and energy (not tabled). The list of the top 20 journals ranked by total articles published highlights the cross-disciplinary spread of journals publishing Sustainable Higher Education research (see Table 2).

The most cited publication is by D'Amato et al. (2017), with 727 citations, showing it is a seminal or foundational piece in its research area. Other top-cited works include Cebrián & Junyent (2015) (288 citations), Pauw et al. (2015) (287), and Wals et al. (2014) (281), all of which likely contribute significantly to ongoing academic discussions. Publications with citations between 150 and 250, such as Borras Jr. et al. (2010) (247) and Franco et al. (2019) (176), indicate strong academic visibility and influence, but may be more focused or recent in nature. Several recent publications (e.g., Fekih Zguir et al. (2021) with 104 citations, and Krishnan & Koshy (2021) with 92) already have notable citations, suggesting emerging relevance and potential for continued influence.

Table 2: No of Citation

S.No.	Document	Citations
1.	D'amato D.; Droste N.; Allen B.; Kettunen M.; Lähtinen K.; Korhonen J.; Leskinen P.; Matthies B.D.; Toppinen A. (2017)	727
2.	Cebrián G.; Junyent M. (2015)	288
3.	Pauw J.B.; Gericke N.; Olsson D.; Berglund T. (2015)	287
4.	Wals A.E.J.; Brody M.; Dillon J.; Stevenson R.B. (2014)	281
5.	Von Wirth T.; Fuenfschilling L.; Frantzeskaki N.; Coenen L. (2019)	268

6.	Borras Jr. S.M.; Mcmichael P.; Scoones I. (2010)	247
7.	Secundo G.; Ndou V.; Vecchio P.D.; De Pascale G. (2020)	218
8.	Sovacool B.K.; Kester J.; Noel L.; De Rubens G.Z. (2018)	212
9.	Donohoe H.M.; Needham R.D. (2006)	210
10.	Vodă A.I.; Florea N. (2019)	197
11.	Ávila L.V.; Leal Filho W.; Brandli L.; Macgregor C.J.; Molthan-Hill P.; Özuyar P.G.; Moreira R.M. (2017)	195
12.	Hostetler M.; Allen W.; Meurk C. (2011)	193
13.	Nchinda T.C. (2002)	191
14.	Franco I.; Saito O.; Vaughter P.; Whereat J.; Kanie N.; Takemoto K. (2019)	176
15.	Burbules N.C.; Fan G.; Repp P. (2020)	151
16.	Shwartz A.; Turbé A.; Julliard R.; Simon L.; Prévot A.-C. (2014)	136
17.	Aikens K.; Mckenzie M.; Vaughter P. (2016)	135
18.	Koester R.J.; Eflin J.; Vann J. (2006)	130
19.	Filho W.L.; Eustachio J.H.P.P.; Caldana A.C.F.; Will M.; Salvia A.L.; Rampasso I.S.; Anholon R.; Platje J.; Kovaleva M. (2020)	124
20.	Leal Filho W.; Brandli L.L.; Becker D.; Skanavis C.; Kounani A.; Sardi C.; Papaioannidou D.; Paço A.; Azeiteiro U.; De Sousa L.O.; Raath S.; Pretorius R.W.; Shiel C.; Vargas V.; Trencher G.; Marans R.W. (2018)	114
21.	Siebrecht N. (2020)	106
22.	Fekih Zguir M.; Dubis S.; Koç M. (2021)	104
23.	Vare P.; Arro G.; De Hamer A.; Gobbo G.D.; De Vries G.; Farioli F.; Kadji-Beltran C.; Kangur M.; Mayer M.; Millican R.; Nijdam C.; Réti M.; Zachariou A. (2019)	96
24.	Sinakou E.; Donche V.; Pauw J.B.; Van Petegem P. (2019)	96
25.	Islam M.M.; Shamsuddoha M. (2018)	95
26.	Riddell A.; Niño-Zarazúa M. (2016)	95
27.	Krishnan V.V.; Koshy B.I. (2021)	92
28.	Miller E.; Buys L. (2008)	89
29.	Sarwar S.; Streimikiene D.; Waheed R.; Mighri Z. (2021)	88
30.	Yusaf T.; Fernandes L.; Talib A.R.A.; Altarazi Y.S.M.; Alrefae W.; Kadirgama K.; Ramasamy D.; Jayasuriya A.; Brown G.; Mamat R.; Dhahad H.A.; Benedict F.; Laimon M. (2022)	85

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Older papers, such as Nchinda (2002) with 191 citations and Donohoe & Needham (2006) with 210, maintain consistent relevance, pointing to their long-term utility in scholarly work. Many documents involve multiple co-authors from diverse backgrounds and institutions, indicating the interdisciplinary and collaborative nature of the research. The works span themes likely related to sustainability, education, policy, innovation, and environmental governance, given the author reputations and institutions typically associated with these topics. Citation counts tend to be higher for older publications, as they have had more time to be referenced. However, some recent papers (2019–2021) show rapid citation accumulation, reflecting their relevance to current academic or societal challenges.

6.2 Authors:

Lozano, R. leads the list with 109 citations and the highest total link strength (2328), indicating not only high individual impact but also extensive collaboration and influence across research networks. Leal Filho, W. follows closely with 95 citations and a strong network presence (2201), suggests a central role in the field. McKenzie, M. also ranks highly with 94 citations and notable total link strength of 1528. Wals, A.E.J. and Wright, T., with 67 and 66 citations respectively, show high link strengths (1327 and 1381), reinforcing their collaborative and interdisciplinary roles. Huisingh, D. stands out with 62 citations and a high link strength of 1467, possibly indicating a role in sustainability or environmental education research. Authors like Ceulemans, K., Lambrechts, W., Gericke, N., and Azeiteiro, U.M. show moderate citation counts (45–49) but high link strength (1000+), indicating strong presence in collaborative or thematic clusters.

Geels, F.W., although having the lowest citation count in the top 20 (38), also has the lowest total link strength (206), possibly indicating more individualized or specialized research not strongly tied into broader networks. Li, J. and Ball, S.J. have mid-level citations (46–47) but relatively lower link strength, suggesting either emerging contributions or a more independent research focus. Authors with higher total link strength often have higher citations, implying a correlation between collaboration/networking and research impact. The list likely represents scholars in sustainability, environmental education, or sustainable development, given the presence of names like Leal Filho, Lozano, Wals, and Huisingh. High citation counts reflect individual impact, while high total link strength indicates integration into the broader academic community. Authors like Lozano R., Leal Filho W., and McKenzie M. emerge as core figures driving the field forward both in terms of ideas and collaborations.

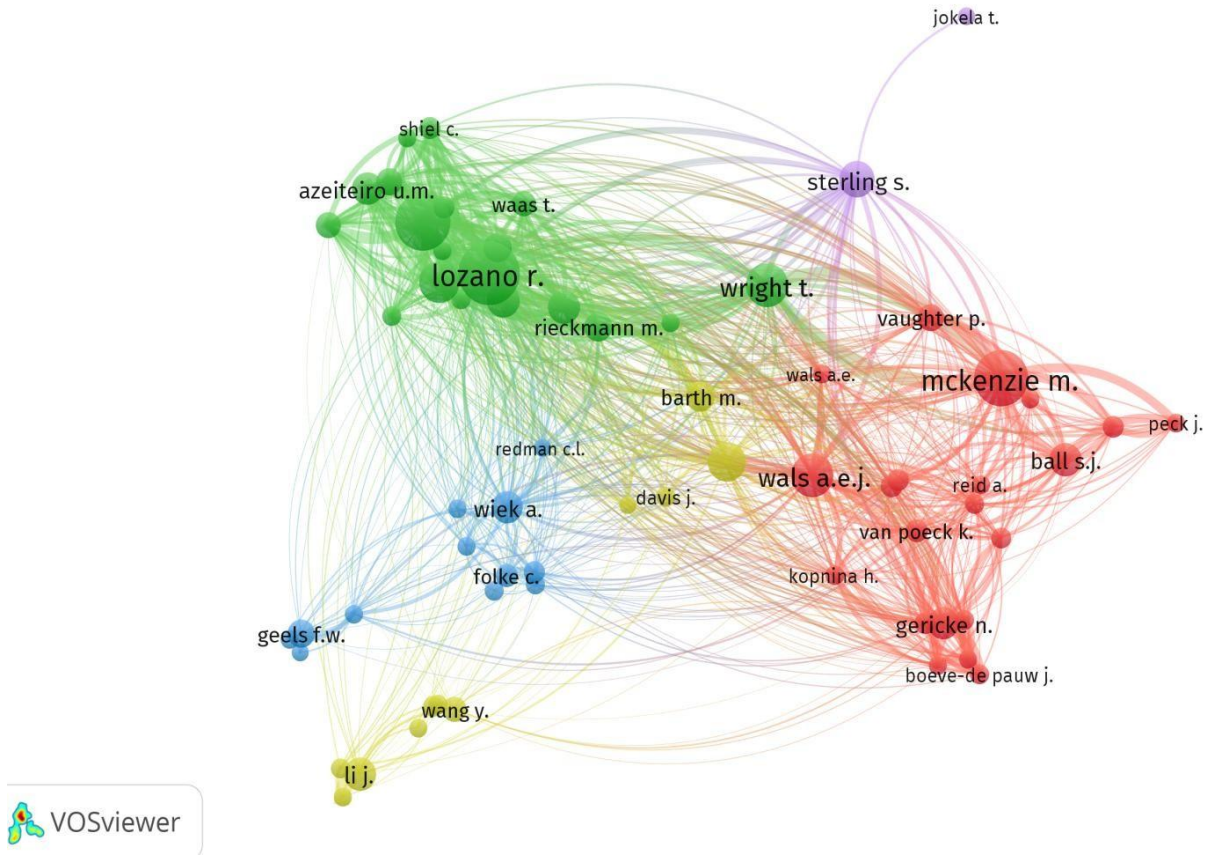

Fig 5 : Name of authors

7. Discussion and Conclusion:

This bibliometric review of the Sustainable Higher Education knowledge base has offered a comprehensive synthesis of the field's growth, geographical distribution, influential actors, and thematic orientations. Drawing from 365 Scopus-indexed documents, the analysis illuminates both the current state and future trajectory of Sustainable Higher Education research, leveraging a combination of descriptive statistics, direct and co-citation analysis, and co-word analysis. The integration of these methodologies through tools such as VOSviewer, Tableau, and Excel has revealed valuable insights into how HESD has matured as a multidisciplinary research domain.

The data extraction and pre-processing phase, which involved cleaning and disambiguating metadata via a thesaurus file, was crucial in enhancing the precision of subsequent analyses. This foundational step mitigated ambiguities related to author names, keyword inconsistencies, and duplicate references, ensuring that the bibliometric mapping and network visualizations accurately reflected scholarly relationships and topic clusters.

One of the most compelling findings is the exponential growth of Sustainable Higher Education literature over the past decade. The publication trajectory clearly delineates three phases: an emergent phase (1999–2016), a steady growth phase (2017–2019), and an accelerating phase (2019–2023). Over 64% of the literature was published after 2019, suggesting that Sustainable Higher Education is transitioning from a nascent area of interest into a rapidly maturing and increasingly recognized academic discipline. This growth is likely driven by the rising global urgency to address sustainability challenges through higher education reform, reflecting broader policy shifts and international sustainability goals, such as the United Nations' Sustainable Development Goals (SDGs).

Despite the increasing volume of publications, the geographical distribution of contributions reveals notable disparities. Scholars from just four countries—the United States, United Kingdom, Australia, and China—account for 55% of all publications. While this dominance may reflect the infrastructural and institutional capacities of these nations, it also underscores a significant imbalance. The underrepresentation of research from developing regions is particularly concerning given the global applicability and necessity of sustainable education solutions. Such geographical skewness may hinder the cross-contextual applicability of insights and pose challenges to the development of inclusive and context-sensitive HESD strategies. Addressing this imbalance is crucial for ensuring a truly global discourse on sustainability education.

The distribution of publications across 152 different journals reflects the multidisciplinary appeal of Sustainable Higher Education. The presence of journals covering education, science, environment, energy,

policy, and engineering indicates that Sustainable Higher Education transcends traditional academic boundaries. This thematic diversity also signals a willingness among researchers to integrate educational goals with technological, ecological, and social systems thinking. The breadth of journals not only amplifies the field's academic reach but also reinforces the notion that sustainability in higher education is a shared responsibility across disciplines.

The citation analysis further identified key publications that have shaped scholarly conversations within Sustainable Higher Education. D'Amato et al. (2017), the most cited work with 727 citations, appears to serve as a foundational text in the field. Other frequently cited articles, such as those by Cebrián & Junyent (2015), Pauw et al. (2015), and Wals et al. (2014), are likely to have introduced influential frameworks, concepts, or empirical findings that continue to inform ongoing research. Notably, several recent papers (e.g., Krishnan & Koshy, 2021) have already garnered significant citations, signaling emerging trends and timely relevance, particularly in the wake of global challenges like climate change, pandemics, and educational disruption.

Author analysis revealed a constellation of scholars who serve as intellectual and collaborative anchors within the Sustainable Higher Education community. Lozano, R., with the highest citation count (109) and total link strength (2328), emerges as a pivotal figure whose work not only garners widespread attention but also bridges multiple collaborative networks. Leal Filho, W. and McKenzie, M. similarly command high citation counts and exhibit robust link strengths, pointing to their centrality in both intellectual and social dimensions of the field. The prominence of these scholars reflects their sustained engagement with core Sustainable Higher Education themes and their role in shaping the field's research agenda.

Interestingly, total link strength provides a nuanced measure of influence that complements citation counts. Authors such as Ceulemans, K., Lambrechts, W., and Azeiteiro, U.M., though not at the top of the citation hierarchy, demonstrate strong link strengths, indicating their integration into active research clusters. Conversely, scholars like Geels, F.W., with relatively low link strength and citations, may represent specialized or emerging subfields that are still gaining traction. The strong correlation between high citation counts and high link strength affirms the value of collaborative scholarship in enhancing academic visibility and impact.

The co-citation and co-word analyses further unravelled the intellectual structure and topical composition of the Sustainable Higher Education knowledge base. Co-citation networks mapped the interrelationships among influential authors, offering insights into epistemic communities and foundational literature. These networks revealed the existence of several distinct but interconnected schools of thought, likely aligned with themes such as curriculum development, sustainability competencies, institutional transformation, and global policy integration. The visual representation of these relationships helps elucidate how knowledge is constructed, shared, and evolved within the field.

Keyword co-occurrence analysis offered a lens into the thematic contours of Sustainable Higher Education literature. Frequently co-occurring keywords highlighted dominant research areas, while their interconnectedness suggested emerging synergies and interdisciplinary integration. Such analysis can be instrumental in identifying research gaps, emerging trends, and potential areas for future investigation. For instance, the presence of terms related to 'innovation,' 'competency-based education,' 'sustainability practices,' and 'policy implementation' may indicate a shift toward more actionable and outcomes-based research.

Overall, the use of bibliometric tools and visual mapping in this review has provided a rich, data-driven portrait of the Sustainable Higher Education knowledge base. It highlights the interplay between academic influence, collaboration, and thematic diversity. Moreover, it affirms the importance of methodological rigor and digital tools in uncovering patterns that might be obscured in traditional literature reviews.

In conclusion, this study offers a robust framework for understanding the landscape of Sustainable Higher Education research. It underscores the field's rapid expansion, identifies leading voices, maps intellectual linkages, and surfaces emergent themes. However, it also flags critical areas for improvement, particularly with regard to geographical inclusivity and balanced representation. As sustainability challenges become more complex and interdependent, the role of higher education in preparing responsive, innovative, and ethically grounded leaders will only grow more vital. Future research should strive to amplify diverse perspectives, deepen theoretical development, and enhance the practical relevance of Sustainable Higher Education scholarship across contexts. The insights presented here serve as a foundation for such endeavors, guiding researchers, educators, and policymakers toward a more sustainable and equitable academic future.

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