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A review of research on environmental awareness based on bibliometric analysis: initiation, progress and future

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ABSTRACT

"Environmental awareness" (EA) is an important factor in helping to eliminate environmental problems and mobilizing individuals and communities. This study addresses the vast literature on EA by presenting a bibliometric analysis of 564 EA studies in the social science citation index (SSCI) in the Web of Science (WoS) database. The study started with a query of EA-related publications in the WoS database and included an exploration stage covering topics such as distribution by years, most cited journals, publishing countries and active universities. The second stage involved the visualization of EA research on keywords through analysis and visual maps using Biblioshiny and VOSviewer software. The third stage involves naming the constructs and identifying their main characteristics. The analysis of keywords and the cluster names made in the light of these words provide a broad perspective of EA research. The final stage, validation, aims to determine the validity of the constructs based on the relationships between concepts. The overall results of the study show that EA research is influential across the world and is shaped around various themes. The identified themes guide future research and policymaking by emphasizing environmental education, sustainability, early childhood education, active learning, and interdisciplinary collaboration.

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1. INTRODUCTION

Today, the growing environmental crisis poses a growing threat to the well-being of humanity and the planet. There are many issues like global warming, over-exploitation of resources, biodiversity crisis and pollution affecting all over the world. These issues are having direct negative effects on living standards, and the well-being of the environment. These problems are emerging as complex and interconnected threats shaped by socioeconomic factors. The urgency of addressing these challenges is raising environmental awareness (EA) and stimulating scientific research. EA plays a vital role in enabling individuals and societies to understand environmental problems and develop effective responses.

The relationship between environmental issues and EA is complex and multidimensional. EA includes knowledge of environmental problems, recognition of their impacts and responsibility for finding solutions. Enhanced EA inspires commitment towards mitigating the effects of environmental challenges and coping strategies to the changing environment. People and even sociocultural units with high EA are focused on using sustainable means of living, advocate for the policies of the protection of the environments and take part in the activities aimed at the conservation of the nature.

Environmental problems have become a major threat to humanity at the global level [1], [2]. According to Dunlap and Jorgenson [3], these problems are spreading globally, both in terms of their existence and impact and the socioeconomic forces that create them. Problems such as climate change, depletion of natural resources, loss of biodiversity and environmental pollution have led to an increase in EA and an increase in scientific research in this field [4]–[6]. Arora *et al*. [7] stressed that the trends if sustained into the future are bound to worsen the situation and threaten the existence of the human race. EA is one of the important forces that motivates people and communities to become aware of the issues that pose risks to the environment and motivates them to take steps towards mitigating such risks [8]–[10]. Scientific inquiry is fundamental in prognosis of the problems regarding the environment, the influence of such problems, and the looking for the way out of such dilemmas [11]–[15]. The development of the research area outcomes heavily assists in developing and enhancing EA, motivating the citizen's support for the environmental policies, and achieving the goals of sustainability [16]–[21].

This research aims to present a bibliometric analysis of scientific publications in the field of EA in the social science citation index (SSCI) index in the Web of Science (WoS) database. This evaluation will enhance comprehension regarding scientific evolution, shifts in publication patterns and central individuals focusing on the area of EA. Furthermore, this bibliometric analysis will assist with the evolution and focus of research in the area of EA. This study aims to highlight significant trends and noticeable areas of research achievements within the scope of EA and will inform future studies. Moreover, there is in the literature on EA, and how varied that literature is, can help develop better approaches to tackle environmental issues.

Bibliometric analysis of EA research helps us understand the growing complexity of environmental problems and highlights the role that scientific research plays in addressing them [22], [23]. This offers the potential to develop more effective strategies for solving environmental problems. EA research promotes public awareness of environmental problems and encourages action to tackle them. It stresses the point that such investigations also serve to improve the environmental policies and practice implementation. Analyzing causes of these scientific contributions helps us in the following. It shows the kind of research carried out within EA in topical terms and in what areas. This, in turn, relates to the understanding of the aspects of focus for the future. It also determines the main authors working in the given domain as well as the articles with wider reach. This helps us in determining who are the experts and leading research in the field. It indicates the countries and institutions that are most active and productive in the EA research. This assists in partnership formation and more efficient allocation of resources. Appreciating the scope and heterogeneity of existing scientific work on EA allows for an enhanced engagement of researchers in the field and many benefits to arise out of this engagement. Assessment findings also shape the agenda for forward looking EA studies. They specify what range of issues requires more attention, which geographical areas are to be given more interest and what approaches are the most fruitful. Overall, this bibliometric assessment underscores the necessity of embarking on research with respect to EA and helps one comprehend scientific advancement in such research and direct future efforts out of it. This study can be a valuable resource for researchers, policy makers and the public who want to contribute to addressing environmental issues and raising EA.

The overall aim of this study is to conduct a bibliometric analysis of scientific research in the field of EA and to understand the scientific developments in this field. In this way, it highlights the scientific contributions in this field, which aims to contribute to the understanding of environmental problems, the assessment of their impacts and the development of solutions. In order to realize the general objective of the research, the following specific objectives of the study will be:

- Identify publication trends of EA research: analyze the publication trends of scientific research on EA from past to present and identify how these trends have changed.
- Identify the most cited articles and leading researchers: identify the most cited articles and leading researchers in the field of EA.
- Identify key topics and focal points: identify the key topics and focal points of the field and determine which topics receive the most attention and research.
- Identify the most productive countries and institutions: identify the most productive countries and important institutions in the field of EA research.
- Understand the size and diversity of the scientific literature: understand the size and diversity of the scientific literature on EA.
- Providing guidance for future research: based on the results of the research, provide guidance for future research in the field of EA.

This study aims to comprehensively examine the development, main trends and influential contributions in the field by analyzing the scientific literature in the field of EA through bibliometric methods. Through the analysis of publications indexed in the WoS database, publication trends in EA research, the most cited studies, leading researchers, and the most productive countries and institutions are identified. The original contribution of the study is to provide a systematic mapping of the field of EA research, highlighting important developments in the field and guiding future research. This analysis sheds

light on the current state and historical development of EA research and provides strategic guidance to stakeholders aiming to raise EA and provide effective solutions to global environmental problems.

2. METHOD

This research was conducted using the WoS database to perform a bibliometric analysis of scientific publications in the field of EA. WoS database was used in the text mining application related to EA. One of the indicators of scientific productivity among various countries is international publications. The indexes of publications constitute an important data in determining the quality. WoS consists of six online databases, one of which is SSCI. Publications related to EA are indexed in SSCI. The main reason for choosing the WoS database is that the VOSviewer and Biblioshiny programs analyze only WoS, Scopus, and PubMed database files.

2.1. Research design

This research adopts a methodology consisting of four main stages. In the first stage, “exploration”, the WoS database is queried for publications related to EA. In this stage, the distribution of EA publications by years, the most cited journals, the countries with the most publications, and active universities are scanned. The second stage is “visualization”. Bibliometrix (Biblioshiny) R programming language and VOSviewer software were used for analysis and visual maps were created. Analysis and visualization were based on the keywords of EA research. The third stage, “identification”, involves naming the constructs and determining the main features of these constructs. In the identification stage, the constructs created in the light of the keywords related to EA were named and supported by the word analysis in the abstracts. The “validation” stage aims to determine the validity of the constructs created based on the relationships between concepts. These four basic stages summarize the theoretical framework. The application of these four stages in the methodology allows for a systematic and rigorous approach to analyzing and understanding EA research. In this manner, researchers will be able to collect, process, and authenticate the data in an efficient manner for more convincing findings and observations. Such stages were utilized to examine the research hotspots, forecast the possible research directions, figure out and visualize various operations with mathematical as well as statistical measures, and validate a huge volume of data [24], [25]. The stages presented in Figure 1 illustrate the mora exact steps that are applied in the bibliometric analysis of EA research.

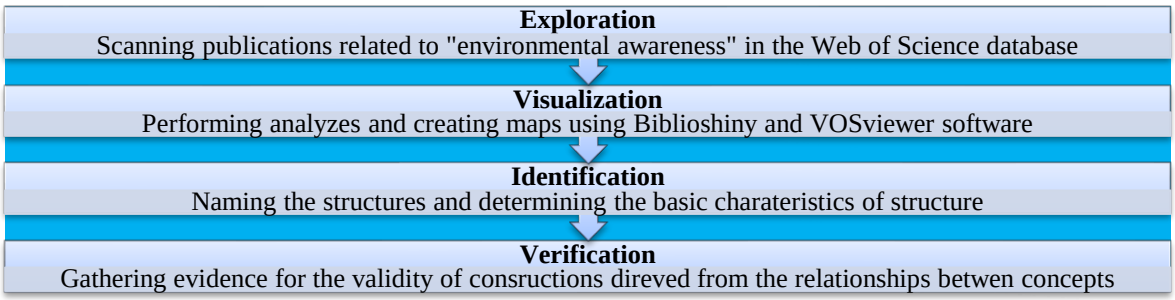

Figure 1. Theoretical framework

The procedures performed in accordance with the stages shown in Figure 1 are listed:

- Data collection: the data analyzed for the study were collected using 564 articles related to EA in the SSCI index in the WoS database. The data were selected from publications between 1987 and 2023.
- Data limitations: the study was limited according to certain criteria. These limitations included publications related to EA and excluded other topics.
- Data download: articles from the WoS database that met the criteria were downloaded as ".bib" and ".csv" files. These files constituted the main data source for the analysis.
- Data analysis: the analysis of the data was carried out in two stages: i) descriptive analysis: downloaded data were annotated with basic descriptive statistics (e.g. number of publications, number of authors) and ii) bibliometric analysis: bibliometric analysis of the data was performed. This stage was carried out using scientific mapping technique.
- Bibliometric analysis tools: as part of the analyses, network analysis maps of the data were created. These maps were prepared using special software such as Biblioshiny and VOSviewer.

- Research categories: the research includes bibliometric analysis on the distribution of EA publications by years, the most cited journals, the most publishing countries, active universities and word categories in the abstracts, focusing on keyword network analysis.

Using these methods, the research conducted a bibliometric analysis of EA research in the WoS database. After analyzing the data obtained and applying the method, we focused on the main findings of the research and how these findings were interpreted. Disclosure of the findings will help to better understand the current state and trends in the field of EA and provide important clues for future research in this field. By employing these techniques, a bibliometric assessment of EA research within the WoS database was carried out. In this case, we analyzed the results and methodology and concentrated on the principal results of this research along with those results interpretation. This understanding of the findings will clarify the current status and development of EA, and will also suggest promising directions for other research within the discipline. however, before proceeding with Figure 2, it is necessary to define the background regarding the exploration and visualization components of the research. In the first phase of the study, a comprehensive search was performed on the WoS database for articles related to "EA," which argued a total of 564 publications. This PRISMA flowchart shown in Figure 2 illustrates the search and selection process described in this study.

Firstly, exploration and visualization stages were carried out in the study. In the research process, publications on "environmental awareness" were scanned in the WoS database and 564 articles were found. The PRISMA flow diagram related to the discovery stage of the study is given visually in Figure 2.

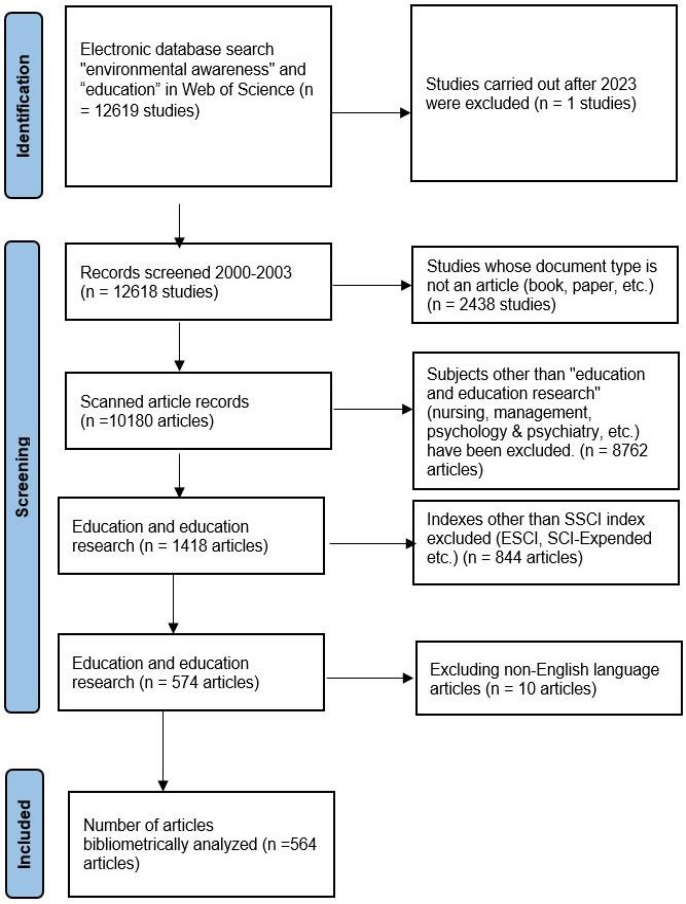

Figure 2. PRISMA flowchart of the exploration stage of the study

3. RESULTS

3.1. Exploration

Data were examined utilizing bibliometric approaches with an aim to keep track of the existing literature on EA and to provide relevant insights for the future development of research in this discipline. The results of the analyses were given and discussed. A bibliometric analysis has been found to be helpful in reviewing the academic work on the field of EA and determining the major players and works in the domain. It is believed that such analyses can be helpful in focusing the researchers on specific problems or tendencies

in the field as well as on possible future collaborations and enhancements. The results can provide guidance to the researchers and students in the field of education and pedagogy on which magazines may be worth their attention. At the same time, citation metrics as well as linking strength are said to be crucial in evaluating the impact of certain journals. Therefore, these indicators should be considered by researchers while appraising these journals for submitting their work or for seeking references. The findings and remarks based on bibliometric data regarding research in EA are presented accordingly. The results of this study, which explored research progress on EA included: i) exploration; ii) investigation; iii) definition; and iv) validation.

The data collected using 564 articles on EA between 1987 and 2023 in the SSCI index in the WoS database were analyzed. General information about the articles on EA is given in Table 1. As seen in Table 1, the average citation per document of articles published in the WoS database between 1987 and 2023 is 66.47. The annual growth rate of 145 journals with 564 articles published on EA is 12.05%. The average document age of the articles written with 25,115 references is 7.05 years. Only 107 of the 1,570 authors wrote articles with a single title. A total of 111 articles have a single author, and the ratio of co-authors per document is 2.94. The international co-authorship rate is 16.13%. Analyzes were started to determine the trend of the number of articles and citations related to EA depending on the change over the years. The graph regarding the publication year distribution is given in Figure 3.

When Figure 3 is analyzed, the first study on EA was conducted in 1987, while no articles were written in 1988, 1990, 1992, 1994, and 1995. Until 2009, the number of articles and citations followed a stable trend, and with this year, the number of articles and citations showed an upward trend, albeit with fluctuations. The highest number of articles and citations was reached in 2021. In 2022 and 2023, the decrease in the number of articles and citations is noteworthy. Figure 4 shows the top 10 authors who published the most articles in the subject area.

Table 1. Main information data of EA

Main information about data	Value
Timespan	1987-2023
Sources (Journals)	145
Documents	564
Annual growth rate (%)	12.05
Document average age	7.05
Average citations per doc	16.47
References	25,112
Author's keywords (DE)	1,832
Authors	1,570
Authors of single-authored docs	107
Single-authored docs	111
Co-authors per doc	2.94
International co-authorships (%)	16.13

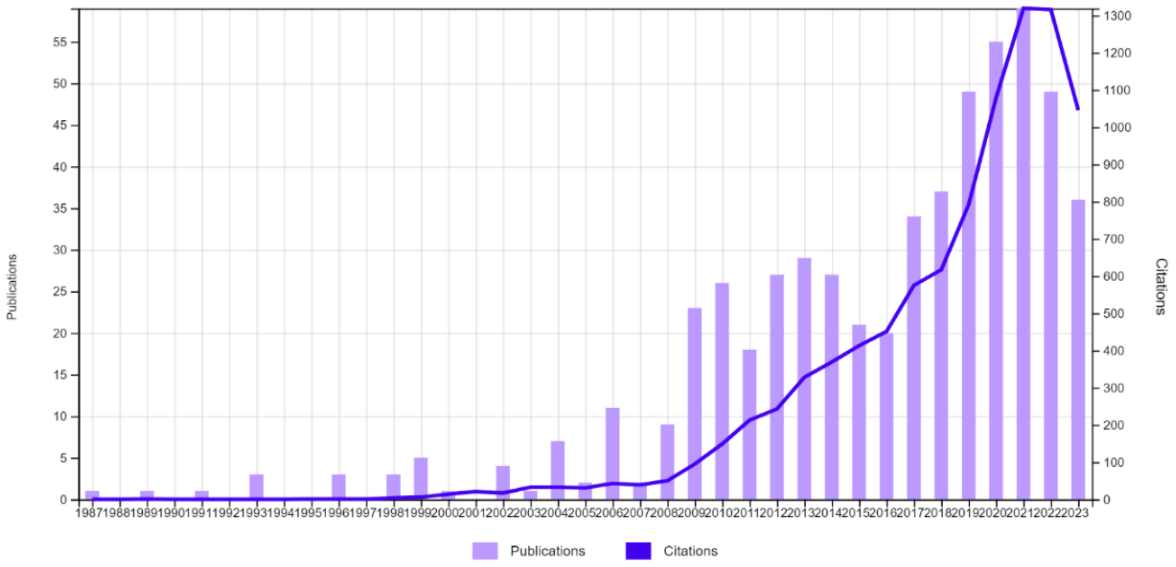

Figure 3. Distribution of articles and citations about EA by year

As shown in Figure 4, the author who produced the most articles on EA is Bogner (f=5). It is seen that Alkaher, Altay, Gündüz, Samuelsson, Schneller, and Tal (f=3) produced articles. Aldrich, Assaraf, and Bardin appear to have published (f=2) articles. Figure 5 shows three field alluvial graphs related to EA.

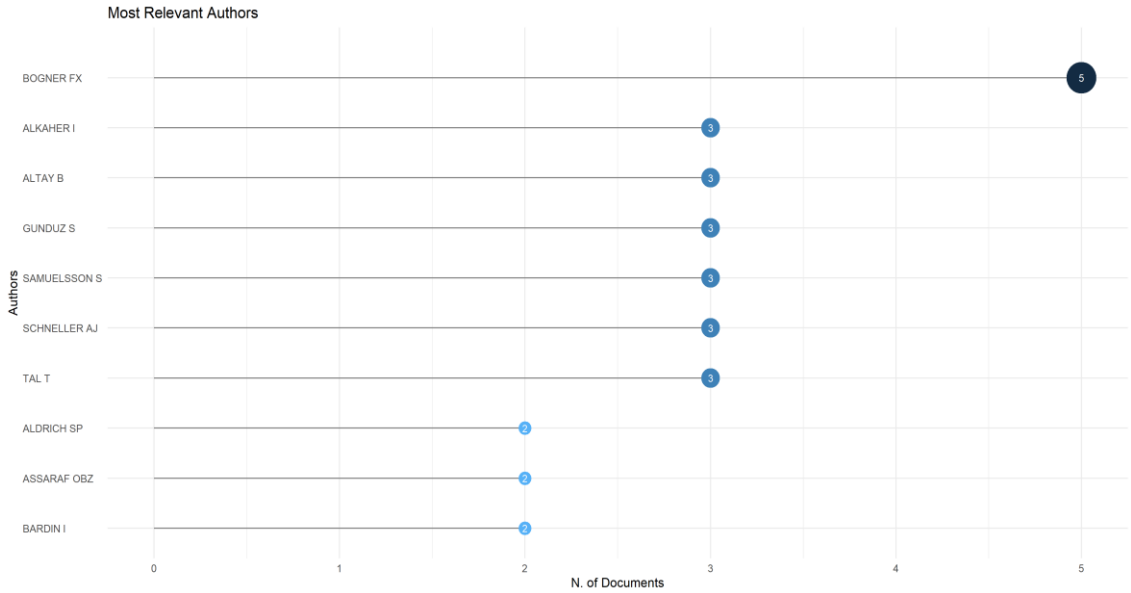

Figure 4. Authors who published the most articles on EA

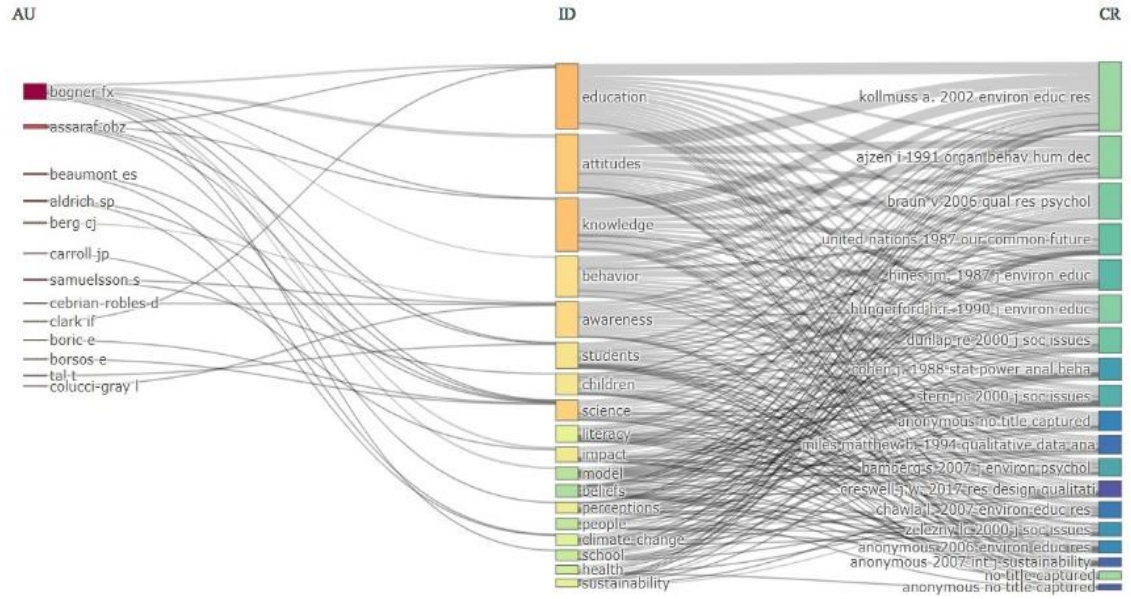

Figure 5. Three field alluvial graph

When Figure 5 is examined, it was created in the Biblimetrix program with the articles in the journals in the right section, authors in the left section, and keywords in the middle section. In this way, it is aimed to reveal the relationship between the most published and cited authors, the most used keywords and the articles published in the best journals. When the keywords are analyzed, it is seen that the most common keywords are "education", "attitudes" and "knowledge" with the largest rectangle size. In addition, in accordance with the focus of this research on scientific articles related to EA, it was found that the keyword "science", shown in orange, was used by most of the authors in the left section. In the right section, the most cited authors and the name of the journal in which they published stand out. The most cited author is Kolmus

and his journal is Environmental Education Research. Figure 6 shows the H index impact local values of the authors. Figure 6 shows that Bogner has the darkest blue color and the highest H index (f=4) and ranks first. Other authors follow this author with frequencies of 3 and 2. Figure 7 shows the cumulative journal growth.

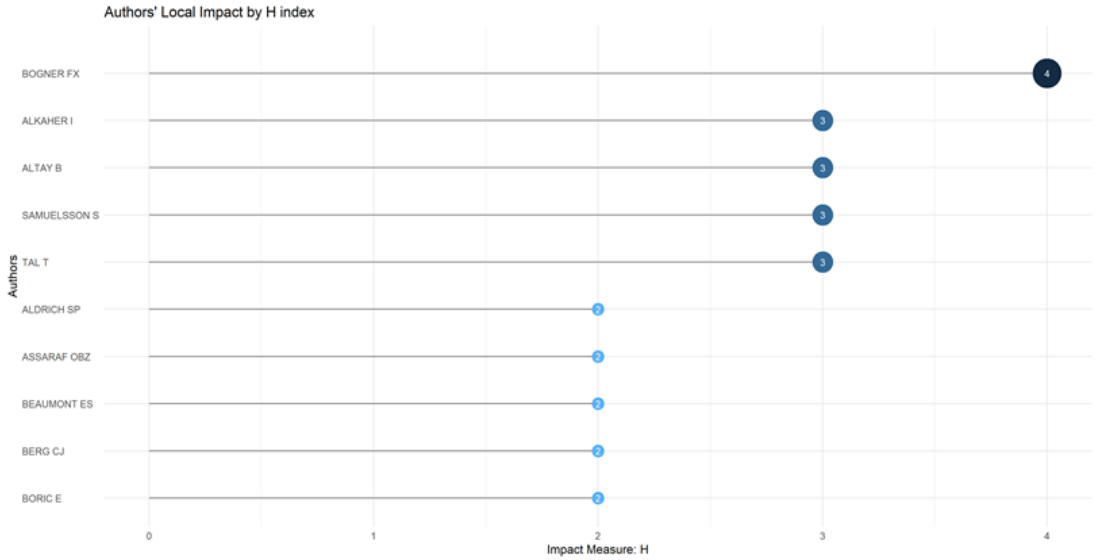

Figure 6. Authors' H index local impact values

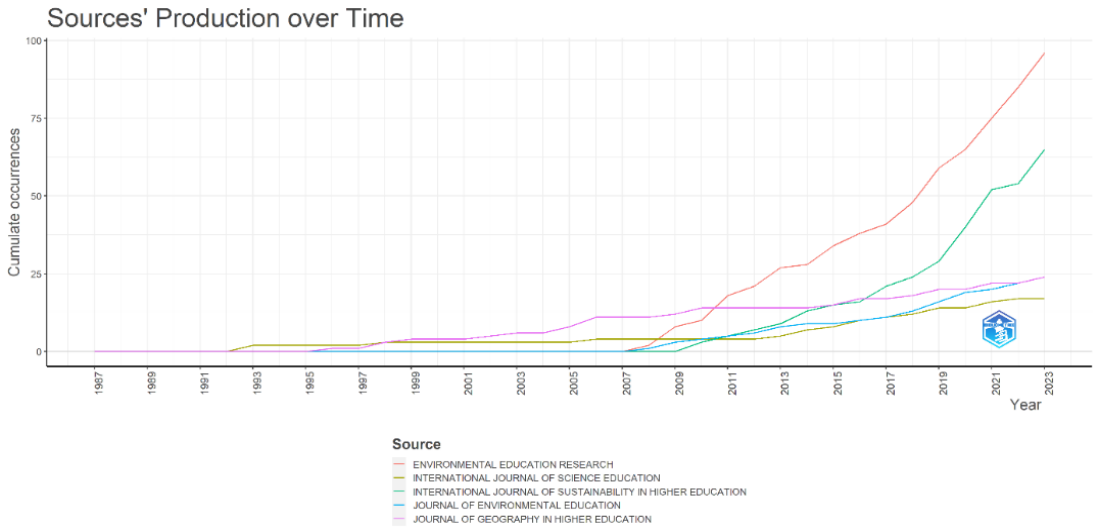

Figure 7. Cumulative graph of journals publishing in EA subject area

Figure 7 shows the cumulative growth of journals publishing on EA. "Environmental Education Research" ranks first with the number of publications (f=96). "International Journal of Sustainability in Higher Education" (f=65) is in second place, followed by "Journal of Environmental Education" and "Journal of Geography in Higher Education" in third and fourth place (f=24). In 5th place is the "International Journal of Science Education" with 17 publications. The top 10 most cited journals related to EA research are presented in Figure 8.

Based on the data in Figure 8, findings about the top 10 journals in which EA research was published were obtained and interpreted. According to the results of the analysis, the most cited journal with 903 citations related to EA is "Environmental Education Research". This journal is followed by "Journal of Environmental Education" (527 citations), "International Journal of Sustainability in Higher Education" (339 citations), "International Journal of Science Education" (330 citations), "Journal of Cleaner Production"

(297 citations), "Journal of Environmental Psychology" (231), "Environment and Behavior" (205 citations), "Sustainability-Basel" (203 citations), "Journal of Research in Science Teaching" (184 citations), and "Journal of Geography in Higher Education" (150 citations). Table 2 shows the 10 most cited publications, their DOI addresses, total number of citations, number of citations per year and normalized citation numbers.

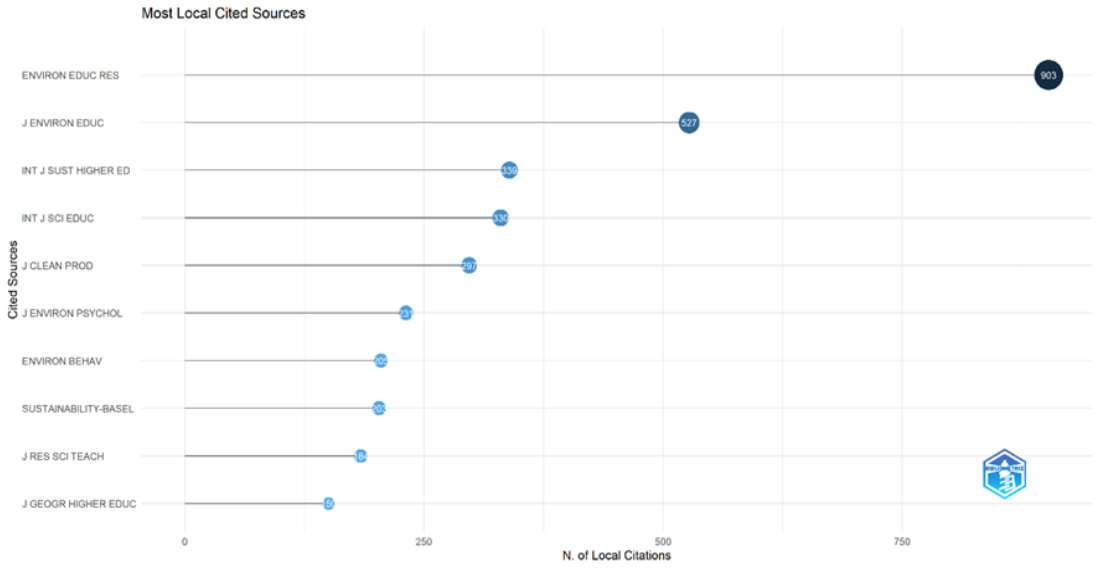

Figure 8. The most cited journals related to EA

When Table 2 is examined, the most cited article is the work of Ballentyne and Packer (f=139). However, according to the normalized total citation score, Kopnina's article with a value of 7.73 was cited the most. This study is followed by Ralph and Stubbs 6.07, Ballentyne and Packer 5.39 with normalized total citations. It should be noted that the normalized total citation score is more important than total citations. Figure 9 shows the countries of the responsible authors and the number of articles in EA publications.

Looking at Figure 9, it is understood that the USA ranks first in terms of publishing with researchers from the same country and researchers from more than one country, and that this country contributes the most to the subject of EA. The USA is followed by the UK, China, Australia, and Turkey. Figure 10 shows the studies conducted by countries in relation to the subject area of EA. The map shows the number of scientific productivities going from dark blue to light blue color. It can be seen that the USA, which has the highest number of articles and scientific productivity in relation to EA, is represented in dark blue (f=528), followed by the UK (f=152) in second place and China (f=139) in third place and represented in lighter blue. The scientific productivity and frequencies, total citations and their frequencies of some countries are given in Table 3. When Table 3 is analyzed, it is seen that the USA ranks first in the total number of citations with 2,152 citations, similar to scientific productivity. However, in terms of the average number of citations per article, the USA ranks behind countries such as the Australia and the UK.

Table 2. Information on the most cited articles on EA

Paper	DOI	Total citations	Total citation per year	Normalized total citation
Ballantyne R., 2011	10.1080/13504622.2010.530645	139	10.69	5.39
Vosniadou S., 1998	10.1080/0950069980201004	126	4.85	2.55
Dori Y. J., 1999	10.1002/(SICI)1098-2736(199904)36:4<411::AID-TEA2>3.0.CO;2-E	126	5.04	2.44
Ralph M., 2014,	10.1007/s10734-013-9641-9	125	12.50	6.07
Wright T., 2010	10.1108/14676371011010057	125	8.93	2.75
Lu S. J., 2015	10.1080/13504622.2014.911247	117	13.00	5.34
Colucci-Gray L., 2006	10.1002/sce.20109	109	6.06	3.75
Stern M. J., 2008	10.3200/JOEE.39.4.31-43	107	6.69	2.10
Kopnina H., 2020	10.1080/00958964.2019.1710444	104	26.00	7.73
Gruenewald D. A., 2004	10.1111/j.1467-873X.2004.00281.x	96	4.80	4.34

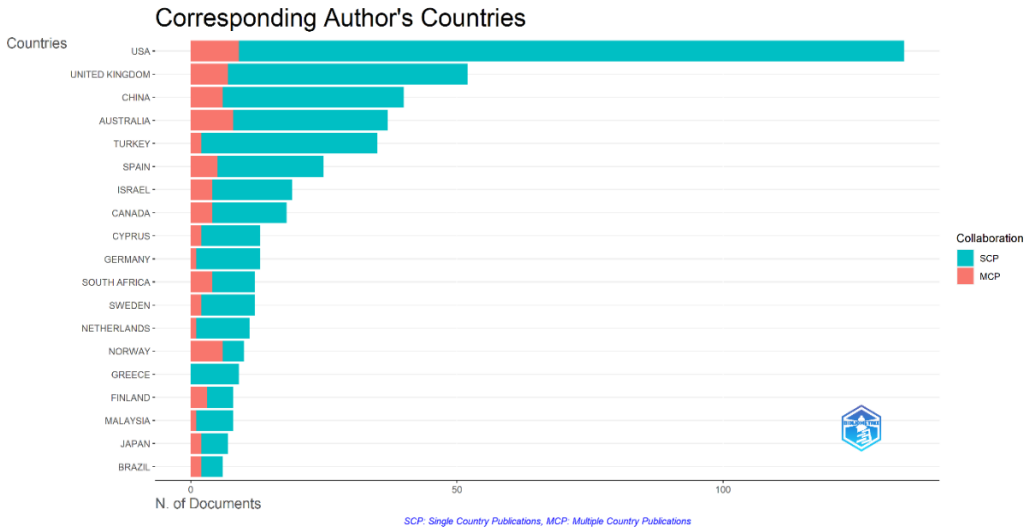

Figure 9. Countries of corresponding authors of EA-related publications and number of articles

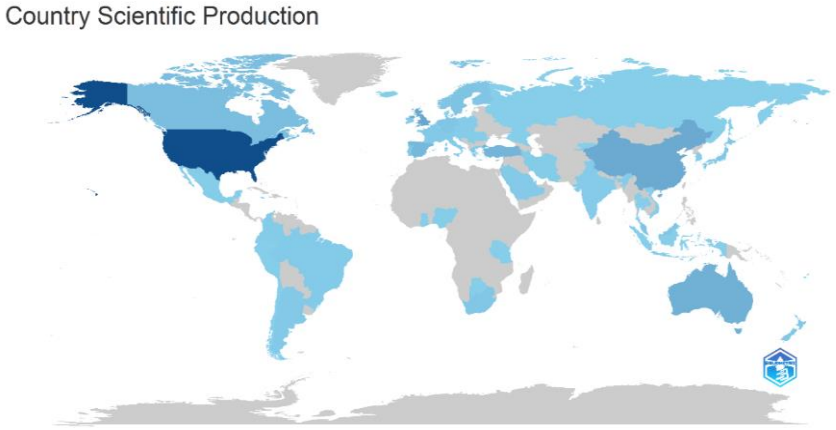

Figure 10. Scientific productivity of countries in EA

Table 3. Countries' scientific productivity and total citations, average number of citations per article

Country	Freq	Total citation	Average article citations
USA	528	2152	16.10
UK	152	904	17.40
China	139	715	17.90
Australia	113	1063	28.70
Turkey	99	354	10.10
Spain	81	334	13.40
Canada	62	342	19.00
Israel	48	403	21.20

Figure 11 shows the publication growth of universities. It is understood that "Univ. Florida", "Near East Univ.", and "Univ. Malaya" with 14 articles each. With 12 articles each, "Hong Kong Inst. Educ.", "Clemson Univ.", "Griffith Univ.", and "Clemson Univ." with 12 articles each. Figure 12 shows the word cloud created from the keywords of the EA topic.

The word cloud in Figure 12 shows the keywords most frequently used by the authors. The keywords in the center, which are larger than the other keywords, were more frequently preferred by the authors. The most frequently used keywords are "education", "knowledge", "attitudes" and "awareness". Since the frequency of other words is relatively lower, it is noticeable that they are further away from the center and smaller in size. Figure 13 shows the trending topics.

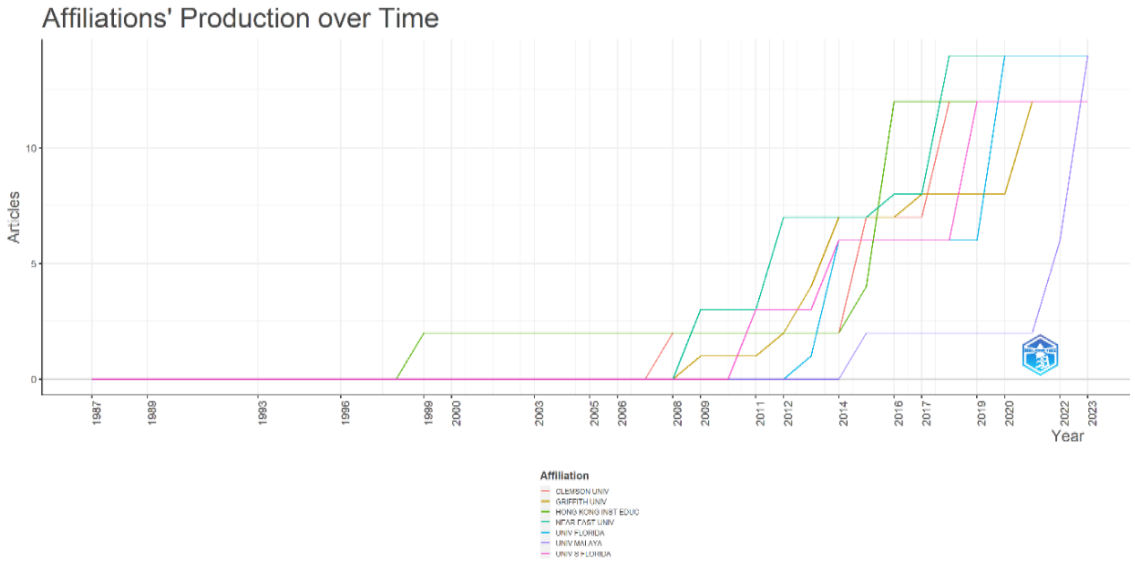

Figure 11. Publication growth of universities regarding EA

Figure 12. Keyword cloud related to EA

When the trending topics related to EA in Figure 13 are analyzed, it is seen that the longest trending topic is "adults" and this trend continues between 2008 and 2020. It is noteworthy that the topic with the biggest bubble is "education" and it is the most trending topic from 2020. In 2022, the figure shows that "competences" and "connectedness" are the trending topics. Figure 13 shows the thematic evolution of keywords related to EA. Before delving into Figure 14, it is important to provide context regarding the thematic evolution of keywords related to EA over time. This evolution is visually depicted in Figure 14, showcasing the transformation and interrelation of key terms across different years.

When the thematic evolution map of author keywords by years in Figure 14 is examined, it is seen that the word "critical thinking" has evolved into "interdisciplinary" over time. We see that "sustainability", one of the first words to appear, has maintained its popularity over the years and has incorporated the words "curriculum" and "environmental" in the first years. It is understood from the figure that the words "environmental", "environmental awareness", "environmental education" and "education" have evolved into the word "environmental education".

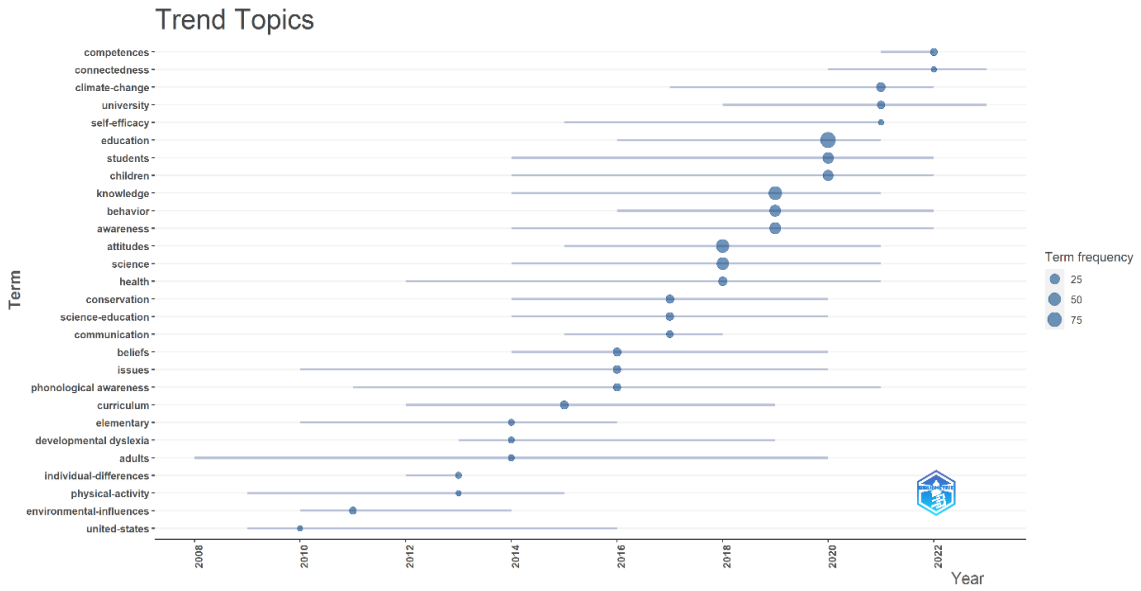

Figure 13. Trending topics related to EA

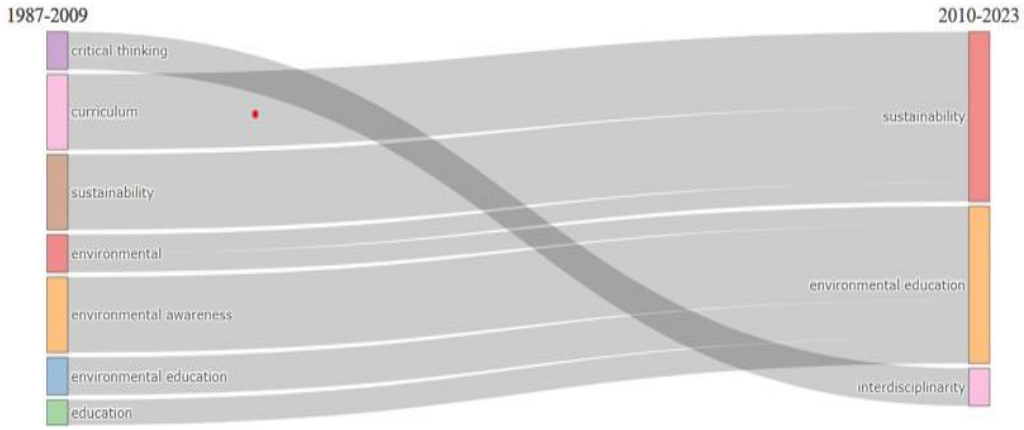

Figure 14. Thematic evolution alluvial graph of keywords related to EA by years

3.2. Visualization

VOSviwer software represents the keywords and abstracts of the articles on EA with three different graphical methods. “Overlay visualization”, “cluster density visualization” and “network visualization” maps are used for bibliometric analysis. The overlay map related to EA is presented in Figure 15. It is considered that the overlay map created with the usage density of keywords related to EA over the years is important in terms of determining the trend of research topics. According to Figure 15, while the keywords “environmental education”, “environmental awareness”, “sustainability”, “higher education” and “sustainable development” are mainly discussed in EA-related studies, keywords such as “climate change”, “education”, “gender”, “youth”, “medical education”, “university students”, “sustainability education”, and “pro-environmental behavior” have come to the fore in recent years. The cluster density map visualizing the clustered structure and density of keywords in EA studies is given in Figure 16.

With the cluster density map, the VOSviewer software not only clusters keywords related to EA, but also reveals how intensively related keywords in each cluster are used. When keywords related to EA are clustered, a map with six clusters, identified by the colors red, green, blue, yellow, ice blue, and pink, is presented in Figure 16. The red cluster includes keywords such as “medical education”, “climate change”, “awareness”, “knowledge”, “behavior”, “pro-environmental behavior”, “gender”, and “youth”. The meaning of the green cluster revolves around the terms “education”, “curriculum”, “outdoor education”, “environmental attitudes”, and “environmental knowledge”. This blue cluster comprises among others

"active learning", "sustainability", "sustainable development", "universities", "students", and "participation". The yellow cluster encompasses the terms "professional development", "early childhood", "education", "science education", "science", and "environmental literacy". In the ice blue cluster, for instance, the meaning of the concepts "education for sustainable development", "interdisciplinarity", "environmental sustainability", "biodiversity", and "green chemistry" is explored. Finally, the pink cluster contains keywords such as "higher education", "sustainable development goals", "science education", and "sustainability literacy". The VOSviewer software shows the network of relationships between the keywords that make up the clusters related to EA with the network map shared in Figure 17.

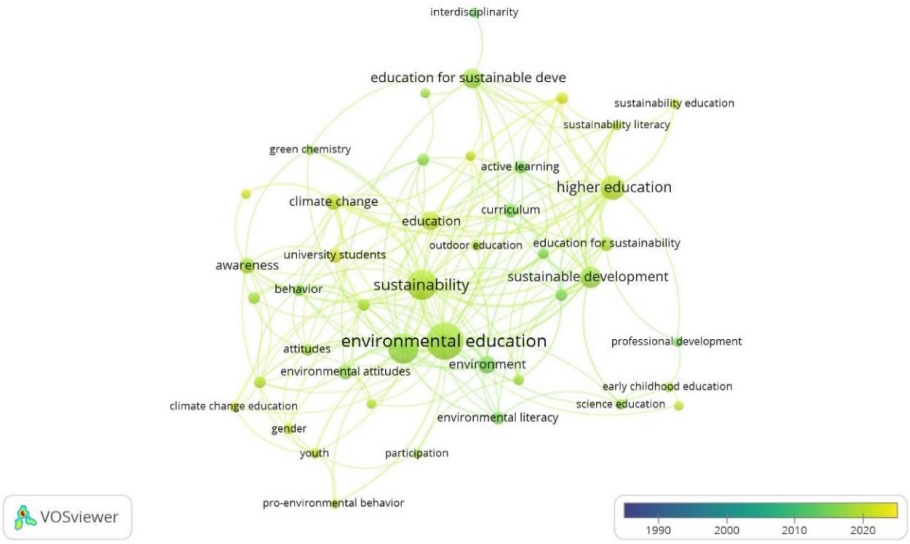

Figure 15. Overlay map of the EA studies

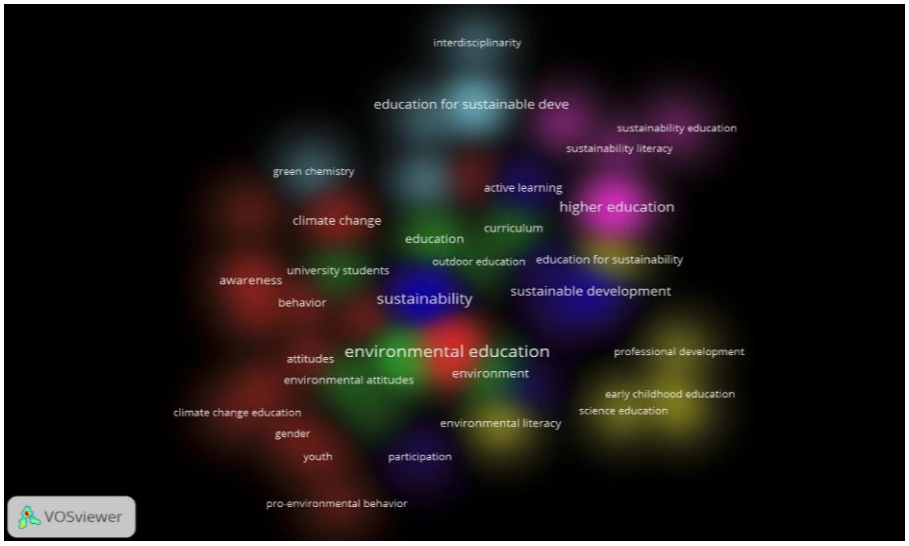

Figure 16. Cluster density map of EA studies

A network map reveals the number of links between a keyword and other related keywords using lines. As the number of these links increases, the circles defining the keywords become larger and the importance of the keyword in the network map increases. When we look at the density of keywords in the map in Figure 17, we can talk about a three-polar structure, namely "environmental education and awareness" (red), "environmental education and curriculum" (green), and "active learning and sustainability" (blue). The less densely connected keyword network, colored on the map as "early childhood and science education" (yellow), "biodiversity and interdisciplinarity" (ice blue), and "higher education and sustainability" (pink), is sandwiched between the tri-polar structure.

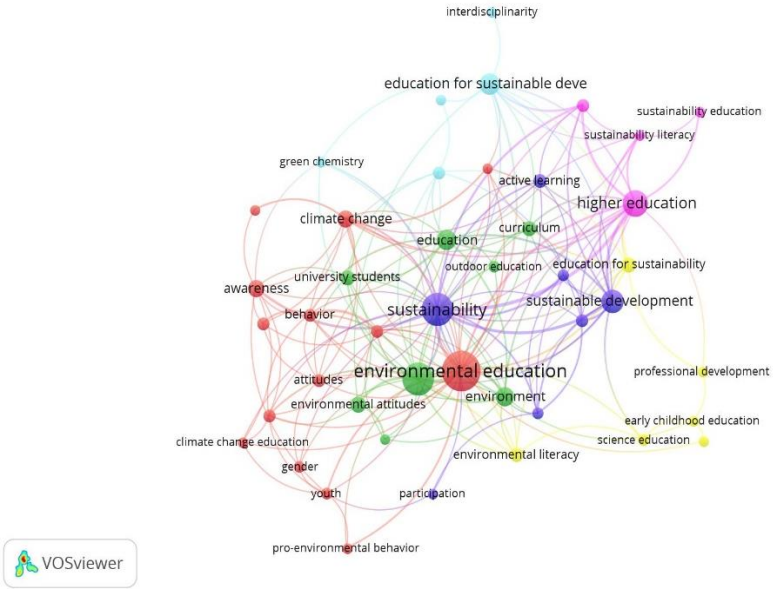

Figure 17. Network map of EA studies

The density and pattern of relationships between keywords in the network map illustrate the key themes in EA research and the important relationships between these themes. The tri-polar structure in the network map shows that the main themes identified (e.g., "environmental education and awareness," "environmental education and curriculum," and "active learning and sustainability") are strongly connected to each other and have significant emphasis in the literature. These three main themes form the cornerstones of EA research, focusing on topics such as environmental education, curriculum development, active learning, and sustainability. Other keywords with less dense links on the map represent perhaps more specific or less emphasized sub-themes. The less densely linked keywords, shown in yellow, ice blue, and pink, are perhaps an attempt to connect the three main themes. This could be an important finding that EA research is expanding into different subfields and moving towards an interdisciplinary approach. The balance between the various colors suggests that research on EA takes a comprehensive and multifaceted approach. Table 4 provides an important visual tool to understand the literature in the field of EA and to provide guidance for future research. Table 4 provides information on the most frequently used words in the abstracts of EA research in the WoS database. The term "occurrences" indicates how many times each word appears in the abstracts, while the "relevance score" represents a measure of the importance of each term within the context of the research based on a specific calculation method.

The word network analysis of the abstracts confirms the keyword analysis. Table 4 shows the most frequently used words in the abstracts of EA research in the WoS database. The occurrence of the word 'student' 907 times reveals that EA research focuses on students. The use of the word 'child' 281 times shows that the research is frequently related to students and children and focuses on competences for these groups. The fact that the words 'attitude' and 'sustainability' are repeated 220 times emphasizes that student attitudes and the concept of sustainability are important in EA research. The use of the word 'teacher' 214 times shows the attention to teacher competences. These findings help us to understand the main themes and focal points of EA research.

Table 4. Information on the words in the abstract

Term	Occurrences	Relevance score
Student	907	0.6105
Child	281	32.819
Attitude	220	0.4452
Sustainability	220	0.9574
Teacher	214	0.6457
University	198	16.394
Learning	190	0.8194
Paper	179	0.6509
Course	170	0.4396
Development	169	0.7933

3.3. Identification

In the identification stage, it is aimed to define the characteristics of each cluster based on the relationships between the keywords and the clusters that make up the keywords. In this way, the identification will be realized and the naming process that brings the keywords in the cluster to a common denominator will be performed. The clusters' color, name and number of occurrences of keywords are given in Table 5.

Table 5 contains a six-cluster structure. In the identification stage, the aim is to define the characteristics of each cluster based on the relationships between keywords and the clusters that constitute these keywords. This process allows for the identification of each cluster and the assignment of names that bring the keywords within the cluster together on a common denominator. The table provides the cluster names, colors, and the characteristics of the highly occurring keywords (number of occurrences) for each cluster. This red cluster is characterized by keywords related to environmental education and awareness. It includes keywords such as "attitude," "attitudes," "awareness," "behavior," "children," "climate change," "climate change education," "environmental education," "gender," "knowledge," "medical education," "pro-environmental behavior," and "teacher education." These keywords occur with varying frequencies. The green cluster is associated with environmental education and curriculum development. It comprises keywords like "curriculum," "education," "environment," "environmental attitudes," "environmental awareness," "environmental knowledge," "outdoor education," and "university students." These keywords are frequently mentioned. This blue cluster focuses on active learning and sustainability. Keywords within this cluster include "active learning," "participation," "pedagogy," "students," "sustainability," "sustainable development," and "universities." These keywords are commonly mentioned. The yellow cluster is centered on early childhood and science education. Keywords associated with this cluster are "early childhood education," "education for sustainability," "environmental literacy," "professional development," "science," and "science education." These keywords are moderately frequent. The ice blue cluster is characterized by keywords related to biodiversity and interdisciplinarity. It includes keywords such as "biodiversity," "education for sustainable development," "environmental sustainability," "green chemistry," and "interdisciplinarity." These keywords occur with moderate frequency. The pink cluster is focused on higher education and sustainability. Keywords in this cluster include "higher education," "sustainability education," "sustainability literacy," and "sustainable development goals." The keyword "higher education" is highly prominent in this cluster. These clusters help categorize and understand the key themes and topics in the given dataset, based on the relationships between the keywords and their respective frequencies.

3.4. Verification

The purpose of the validation stage is to evaluate how well the VOSviewer findings correlate to the publications being analyzed, and to confirm the clusters found and their features through the analysis of word occurrence and interaction within each cluster. The consistency between word frequency analysis and cluster characteristics is evident. The word frequency analysis shows that certain keywords such as "student", "child", "attitude", "sustainability", and "student" have high repetition rates in the abstracts related to EA research. These keywords are also prominent in the identified clusters, providing a validation of the domains of the clusters. The cluster containing keywords related to "environmental education and awareness" is consistent with the word frequency analysis of terms such as "environmental education", "attitude", and "awareness". This concordance has been observed in many studies [26]–[34]. The cluster focusing on "environmental education and curriculum", "curriculum", "education", and "environmental awareness" [30], [35]–[37]. The cluster around "active learning and sustainability" overlaps with the word frequency analysis of terms such as "active learning", "sustainability", and "sustainable development". This overlap can be seen in previous studies [38]–[43]. The cluster "early childhood and science education" is compatible with terms such as "early childhood education" and "science education" identified in the word frequency analysis. Examples of studies confirming this congruence can be seen in previous literatures [44]–[48]. In particular, Torquati *et al*. [49] clearly demonstrate the alignment of nature, science and environmental education in early childhood education, including the interrelatedness of human and natural systems. The cluster associated with "biodiversity and interdisciplinarity" overlaps with word frequency analysis of terms, such as "biodiversity", "education for sustainable development", and "interdisciplinarity" [50]–[54]. It can be seen from the studies in the literature that the cluster associated with "higher education and sustainability" is in harmony with the term "higher education" determined in the word frequency analysis [55]–[59].

The clusters not only validate the word frequency analysis but also provide a deeper classification of the main themes in EA research. These themes include environmental education, curriculum development, active learning, sustainability, early childhood education, science education, biodiversity, and higher education. Research emphasizing the importance of biodiversity and sustainable environment through active learning in science and environmental education in early years and higher education is particularly prominent [30], [60]–[62]. Overall, word frequency analysis confirms the consistency between cluster characteristics and word frequency analysis, reinforcing the themes identified in EA research.

Table 5. Description of cluster names and highly occurring keywords

Cluster color	Cluster name	Highly occurring keywords (number of occurrences)
Red	Environmental education and awareness	Attitude (7), attitudes (7), awareness (12), behavior (7), children (7), climate change (12), climate change education (5), environmental education (63), gender (6), knowledge (7), medical education (5), pro-environmental behavior (5), teacher education (5), youth (6)
Green	Environmental education and curriculum	Curriculum (9) education (16), environment (15), environmental attitudes (10), environmental awareness (43), environmental knowledge (5), outdoor education (6), university students (9)
Blue	Active learning and sustainability	Active learning (8), participation (5), pedagogy (6), students (6), sustainability (42), sustainable development (22), universities (7)
Yellow	Early childhood and science education	Early childhood education (5), education for sustainability (9), environmental literacy (8), professional development (5), science (5), science education (6)
Ice Blue	Biodiversity and interdisciplinarity	Biodiversity (5), education for sustainable development (18), environmental sustainability (7), green chemistry (5), interdisciplinarity (5)
Pink	Higher education and sustainability	Higher education (28), sustainability education (5), sustainability literacy (5), sustainable development goals (7)

4. DISCUSSION

Based on the bibliometric analysis results, conclusions were drawn to highlight the importance of EA research and its impact worldwide. Bibliometric analysis of EA research reflected the size and diversity of documents and studies in this field. In this bibliometric analysis, an overview of EA research is presented. 564 articles published in WoS (SSCI index) between 1987 and 2023 were analyzed. The annual growth rate is determined as 12.05%. The average number of citations per article is 16.47. It was written by 1,570 different authors, 107 of which have a single author. The international co-authorship rate is 16.13%. EA research, which started in 1987, followed a stable course until 2009, and then showed a fluctuating increase. 2021 is the year with the highest number of articles and citations. Bogner is the author who produces the most articles. 'Environmental Education Research' is the journal with the most publications and contains 96 articles. The most influential journal in terms of citations is 'Environmental Education Research'. The USA is the largest contributor to EA research. Although the USA continues to lead in the total number of citations, it lags behind countries such as Australia and the UK in the average number of citations per article. The bibliometric analysis of the application of the theory of planned behavior in environmental science by Si *et al.* [24] also found that the USA, Mainland China, the UK, and Malaysia are the most productive countries. According to Nita [63], the United States is the most productive country and the UK ranks second in terms of productivity. In all three studies, as in our research, the USA and the UK are in the leading position. 'Univ. Florida', 'Near East Univ.', and 'Univ. Malaya' are the universities with the most articles. Among the keywords, "education", "knowledge", "attitudes", and "awareness" are the most frequently used. The topic 'adults' has shown a long-term trend. The topic 'education' has the biggest bubble and has been the most popular topic after 2020. The word 'critical thinking' has evolved over time into the word 'interdisciplinary'. The word 'sustainability' has remained popular and has incorporated other topics. Khanra *et al.* [64] in their analysis of sustainable development, identified four themes that influence sustainability: ecological conservation, residents' interests, carbon footprint, and tourists' behavior. The results of our analysis help us to understand developments in this field by showing the general trends of EA research, prominent authors, journals, countries and keywords.

In this piece of work presented, the results consist of various graphical representation of keywords and article abstracts on the topic of EA. It is a map showing the density of the most used keywords in EA studies over the years. Among the keywords, 'environmental education', 'environmental awareness', 'sustainability', 'higher education', and 'sustainable development' stand out. In recent years, words such as 'climate change', 'education', 'gender', 'youth', 'medical education', 'university students', 'sustainability education', and 'pro-environmental behavior' have come to the fore. In the map, which visualizes the cluster density of EA-related keywords with the VOSviewer software, it is divided into six separate clusters with red, green, blue, yellow, ice blue, and pink colors. Keywords specific to each cluster and the density of these words were determined. It is a network map showing the relationships between VOSviewer software and EA-related keywords. Through the connections between keywords, main clusters such as 'environmental education and awareness' (red), 'environmental education and curriculum' (green), and 'active learning and sustainability' (blue) were identified. Clusters with less dense connections were also observed, such as 'early childhood and science education' (yellow), 'biodiversity and interdisciplinarity' (ice blue) and 'higher education and sustainability' (pink). Similarly, Li and Zhao [65] stated that current environmental assessment research emphasizes hotspots such as "biodiversity" and "climate change" and this trend is likely to continue in the future. Study by Si *et al.* [24] emphasized that waste management, green consumption, climate and

environment, saving and conservation, and sustainable transportation are priority research topics. Study by Mishra *et al*. [25] identified a consistent increase in the number of studies and citations on indigenous communities related to environmental protection, natural resources and economic development over the last four decades. The visualizations in our research help us understand the evolution of keywords in EA research, clustering trends, and relationships between major clusters. In particular, the popularity of certain words over time provides important insights into the density of specific topics and clusters. This data can be a valuable resource for identifying research trends and focal points.

The results obtained through the validation process of the research show that there are distinct themes and key concepts in the EA research literature. First, the 'environmental education and awareness' cluster is heavily associated with keywords such as environmental education, attitudes, and awareness. This reveals that environmental education studies aim not only to transfer knowledge but also to shape individuals' attitudes and awareness. Secondly, the 'environmental education and curriculum' cluster includes the concepts of environmental education, curriculum development and EA. This reflects a theme that emphasizes efforts to integrate environmental issues into the educational curriculum and raise EA among students. Third, the 'active learning and sustainability' cluster includes terms such as active learning, sustainability and sustainable development. This result shows that environmental issues are addressed not only theoretically, but also through an applied and participatory learning process. Fourth, the 'early childhood and science education' cluster includes terms such as early childhood education and science education. This result reflects studies on environmental education focusing on the early stages of life and considering science as a part of EA. Finally, the 'biodiversity and interdisciplinarity' cluster includes terms such as biodiversity, sustainable development and interdisciplinary work. It exhibits that environmental studies focuses on the integration of various concepts within a research work rather than fitting everything into one discipline. From the cluster analysis, it can be deduced that assessments of environmental impacts research is broad and all-inclusive. Topics that emerged include environmental education, sustainability, early years' education, and even research integration among others, which implies that several angles and approaches exist. From these findings, it is possible to give an indication of the direction of future research in the areas concerned.

Study by Shehawy and Khan [26] on how the attitudes of consumers towards the environment affect their green purchasing behavior are comparable to the overall scope of EA research which was presented in the bibliometric analysis of the study. Shehawy and Khan [26] focus on the connection between consumer behavior and environmental consciousness resonates with the themes identified in our study, particularly the emphasis on environmental education and awareness. Understanding, for example, what mindset or level of awareness orders the propensities for buying green, would aid researchers or policymakers in course of straining for tackling an environmental problem or encourage proper and truthful consumption patterns. This relationship stresses the contemporary importance and purpose of the studies of EA: their role in practicing activities where marketing affects the people's health as well as in the battle for a cleaner environment.

The findings of Zha *et al*. [66] regarding the bibliometric analysis of Sponge City research offer valuable insights that parallel the trends observed in EA research discussed in our study. Both studies utilize bibliometric analysis to assess the scope, growth, and international collaboration within their respective fields. Zha *et al*. [66] focus on Sponge City research demonstrates a similar pattern of increasing scholarly interest and collaboration, with China emerging as a prominent contributor in both studies. Furthermore, terms like "Sponge City" in the work of Zha *et al*. [66] and "environmental education" in the context of our work indicate growing interest and research concentration on sustainable urban water management and environmental education respectively. The research on Sponge City development in the cities around the world is interdisciplinary, which is in accord with the various issues found within the research on environmental education and their interconnectedness in relation to the environment.

Ye *et al*. [67] for instance, present the bibliometric analysis in the paper, which emphasizes the current state and dynamics of the corporate social responsibility (CSR) in the scope of sustainable development (SD) research. Similar to our research examining EA, Ye *et al.* [67] point out that this area has attracted increasing number of researchers, especially interested in the relation of CSR and SD. The data presented by Phulwani *et al*. [68] on the study of recycling behavior complements the outcomes of our bibliometric analysis on EA research. Both researches indicate trends that show the increasing need for behaviors that are in tandem with sustainability objectives. While the focus of Phulwani *et al*. [68] research is on recycling and its behavioral aspects, our study addresses wider issues pertaining to EA research, including environmental education, sustainable development, and collaboration between different disciplines. The validation process of our research confirms the consistency between word frequency analysis and cluster characteristics, reinforcing the identified themes in EA research. Specifically, the clusters identified in our study align closely with key concepts such as environmental education and awareness, curriculum development, active learning, sustainability, early childhood education, science education, biodiversity, and higher education. These clusters reflect the multifaceted nature of EA research, emphasizing diverse

perspectives and methodologies. The parallelism between the two studies highlights the growing interest in behaviors and practices that contribute to sustainability and provides valuable information for policy makers, industry stakeholders and researchers aiming to tackle environmental issues. In conclusion, the findings of our bibliometric analysis, together with previous research in the field, reveal the importance of EA research in understanding and solving environmental problems. By identifying main trends, influential authors and research gaps, our analysis contributes to the ongoing debate on EA and sustainability.

5. CONCLUSION

This bibliometric analysis presented offers a comprehensive overview of EA research, revealing distinct themes, trends, and developments. Through the identification of key themes, such as 'environmental education and awareness', 'environmental education and curriculum', 'active learning and sustainability', 'early childhood and science education', and 'biodiversity and interdisciplinarity', this study demonstrates the diverse dimensions of EA research across various disciplines. The frequent occurrence of terms like 'education', 'knowledge', 'attitudes', and 'awareness' among keywords underscores the strong connection between EA research and phenomena related to education, knowledge dissemination, attitudes, and awareness. Visual representation tools further elucidate the evolution of EA research over time, changes in the popularity of specific words, and the relationships between major themes. In general, the study demonstrates how EA research has evolved and earned its place globally with a growing variation in the scope of the discipline. Thus, the outlined themes can be beneficial to any future researchers, policymakers, and teachers who opt to enhance the knowledge in the scope of EA. By shedding light on the overall contribution of EA to research and advancements in the field, this study contributes to our understanding of the importance of EA in addressing environmental challenges and promoting sustainability.

In order to better understand the evolution of keywords over time, more specific studies could be conducted that examine the popularity, frequency of use and seasonal changes of specific keywords. More detailed analyses by geographical regions could be conducted to understand regional differences in EA research; this could help us better understand the effects of various cultural and geographical contexts on EA. Also, more specific analyses could be conducted to understand the different perspectives of social groups such as youth, adults, women or specific ethnic groups. Research examining how the knowledge gained can be applied to environmental policy making, developing educational strategies and sustainability projects could assess the practical implications of EA.

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This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMEN

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [AÖ], upon reasonable request.

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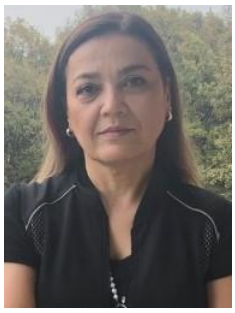

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