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Implementation of ESD in school geography: Bibliometric analysis of 2015-2024 publications in scientific databases

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Abstract

Society can move towards sustainable future by integrating interdisciplinary knowledge in education for sustainable development (ESD), promoting sustainable practices. ESD is closely related to geography. It can be said that the educational content of the subject of geography includes almost all the goals of sustainable development. We reviewed scientific publications in the main collection of Web of Science, Scopus, and Dimensions databases as a result of systematic analysis of literature. We selected 24 articles in accordance with the research questions of the theoretical basis and practice of ESD implementation in school geography with the use of qualitative content analysis. The results obtained have revealed that the subject of geography at school has not lost its importance as a leading subject in the promotion of ESD. We propose prospective research in this area in order to improve the educational content and teaching practices of school geography in promoting ESD.

Keywords: sustainable development goals, ESD, school geography, bibliometric analysis, scientific databases

INTRODUCTION

Education for sustainable development (ESD) plays an important role at all levels of education and as a key component of quality education aimed at comprehension and addressing sustainable development issues in various disciplines. All educational institutions will be guided by ESD principles in educating the generation capable of addressing sustainable development issues and possessing necessary important competencies needed to contribute to sustainable future.

ESD has been recognized as a key factor in sustainable development and an integral element of quality education as a key component of the 2030 Agenda for Sustainable development (Agbedahin, 2019). ESD is a dynamic concept that evolves in response to emerging sustainability issues, which in turn highlights the need for constant adaptation and innovation in educational approaches (Shulla et al., 2020). ESD is considered as an important component of modern education aimed at providing current and future generations with the knowledge, skills and values necessary to solve global problems from this point of view (Violanda & Madrigal, 2021). The shift in education towards sustainability goals comes from the comprehension of necessity that the traditional educational methods need to be adapted to meet the needs of rapidly changing world (Jegstad et al., 2018).

Bezeljak et al. (2020) described ESD as a comprehensive approach that integrates knowledge and actions to promote transformative learning and sustainable development. The implementation of ESD in the educational process is not only an additional aspect of education, but a very important component of the work of educational institutions (Cheng & Yu, 2022; Fredriksson et al., 2020). The UN decade of education for sustainable development held by UNESCO emphasized the importance of integrating the principles of sustainable development into education systems (Pauw et al., 2015). Studies have highlighted the importance of integrating ESD principles at all levels of education,

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Contribution to the literature

- Primary data sources for this study were carefully selected from Web of Science (WoS), Scopus, and Dimensions databases.
- The report presents a bibliometric analysis of publications on the implementation of ESD in school geography for the period 2015-2024, including the landscape, significant research trends and prospects for future research.
- The study identified the most prominent authors who had the greatest influence on research trends related to the implementation of ESD in geography.

including secondary school education, to provide learners with a deep understanding of sustainable development from an early age (Ismail et al., 2024; Olsson et al., 2022; Tsai et al., 2021; Yuan et al., 2021).

At present, ESD extends beyond formal education and includes non-formal education, through this it focuses on continuous learning and emphasize the integration of critical and transformative principles (Noguchi, 2017). In this case, it is very important to integrate sustainability values and ethical considerations into the practice of education in ESD (Laub, 2022). Because, ESD is not only focused on theoretical education, but also on the practical application of this knowledge for sustainable future and emphasis on behavior change (Vilmala et al., 2022). ESD plays an important role in knowledge dissemination and interdisciplinary comprehension of sustainable development issues (Pauw et al., 2015; Veidemane, 2022).

Education about sustainable development should be implemented in the course of teaching general subjects at school. But, the subject of geography, which provides knowledge about the regularities of spatial organization of society and nature, has a special place in this system. The Commission on Geographical Education of the International Geographical Union published the Lucerne Declaration on geographical education for sustainable development (Haubrich et al., 2007), which lays the foundation for an ideal transdisciplinary approach to geographic education.

The current relevance of the Lucerne Declaration is highlighted by the changing landscape of geography education, especially within the framework of technological advances and changing pedagogical paradigms. The emergence of digital tools and platforms has given possibility to students to interact with geographic content from different locations. The use of information technology in field works in geographic education has changed the way that learners interact with geographic data and this has given the possibility to visualize and analyze the data at definite time (Phantuwongraj et al., 2021). The Lucerne Declaration also emphasizes the importance of geographic education in promoting global citizenship. The Declaration emphasizes the importance of geographic literacy for understanding global issues, highlighting the need for geographic knowledge to solve issues such as climate change, migration and urbanization. As geography education continues to adapt to modern demands, the founding ideas of the Lucerne Declaration remain a guiding framework for educators who strive to prepare learners for complex and interconnected world.

The subject of geography not only creates a basis for learners to understand the complex relationships between society and environment but also plays a special role in the development of ESD by increasing awareness of sustainable development and integrating the principles of sustainable development into the curriculum (Guo et al., 2018; Pauw et al., 2015). Therefore, geographic knowledge is an important tool for understanding the complex unity of sustainable development goals (SDGs) and ways to achieve sustainability (Meadows, 2020). As researchers have pointed out, the content of geography is the most appropriate for education with the purpose of sustainable development compared to other subjects, that is, in geographical education, there arises an opportunity to form sustainable development competencies by explaining spatial relations and interaction with the environment (Miao et al., 2022). Thus, geography is recognized as the main discipline for promoting sustainability in some countries (Borg et al., 2012; Brkić-Vejmelka et al., 2018; Danaher et al 2021; Guo et al., 2018; Hawa et al., 2021; Walshe, 2008). However, the subject of geography will reveal its real potential only if it relies on the advanced experience of scientific knowledge and teaching about the global problems of modern humanity in spreading and explaining the ideas of sustainable development. Enriching school geography curricula with the content on sustainable development gives us the possibility to use the unique potential of this subject.

In our study, we set out to analyze the research potential of the subject of geography for the promotion of ESD on the basis of specific bibliometric data and identify outstanding studies in the integration of ESD into school geography. Regarding the research aim, the following research questions have been considered in our review:

1. What does the bibliometric map of ESD study in school geography look like?

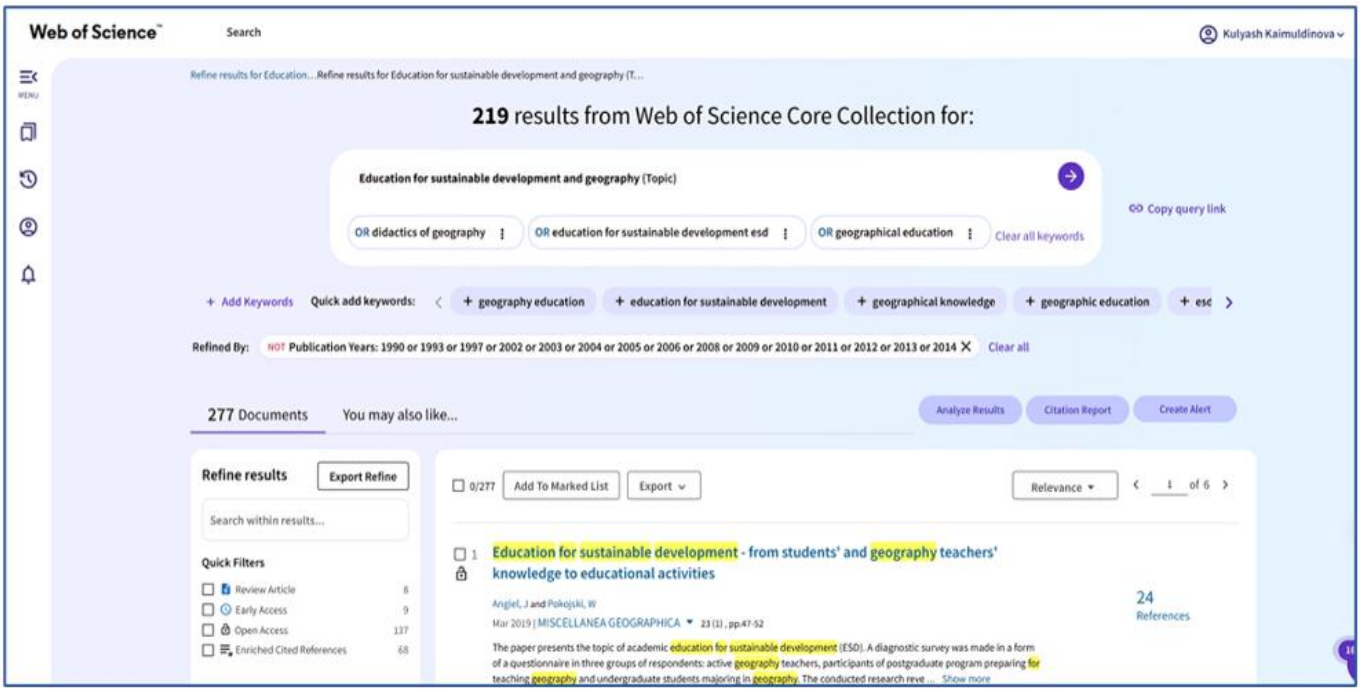

Figure 1. The process of selecting publications by subject in WoS database (Source: Authors' own elaboration)

2. Which authors contribute to the study of ESD in school geography?
3. Current state and technologies for implementing ESD in school geography

METHODS AND RESEARCH MATERIALS

Search For Sources and Selection Strategy

The search strategy was carried out in accordance with the PRISMA protocol (Page et al., 2021). Our large-scale search was carried out on the key words "education for sustainable development and geography", in addition, for the purpose of clarification, in addition, key words "implementation of ESD in school geography", "ESD in school geography", "ESD and curriculum geography", "ESD teaching in school geography", "effective practice of ESD in school" were used. Publication data for analysis were obtained from WoS, Scopus, Dimensions scientific databases that can be integrated with VOSviewer software.

In the selection of publications for the review, all types of publications (articles, conference materials and books and their chapters) related to school geography and sustainable development were included according to the "Inclusion criteria" (inclusion criterion), there were no restrictions on the language of publication and type of research. To ensure that the data is up to date, only publications published within the last ten years (2015-2024) are included. According to "exclusion criteria" (exclusion criterion), the review included other subjects related to higher education, specific school geography and repeated publications were excluded. These requirements were used in our review to accurately reflect the state of ESD in school geography based on original research articles.

It was found that 277 publications related to the search of key words "education for sustainable development and geography" on WoS, in addition to these key words "didactics of geography", "geographical education", "geographical knowledge" were used. As a result of filtering, 219 publications were selected for the period 2015-2024 (**Figure 1**).

Next, it was found what research areas publications cover, since some publications cover several areas, the total number of publications and their shares make a difference from the initial number (**Table 1**).

The inclusion criteria also considered the inclusion of SDGs in the publications. Accordingly, we considered the provision of SDGs using the "categories" subsection of WoS platform (**Table 2**).

Analysis of the titles and abstracts of the publications on WoS gave the possibility to identify publications on the issues under study in more detail. A further meta-analysis was performed on these publications. 645 publications were identified as a result of the initial search in the Scopus database on the key word "education for sustainable development and geography" (education AND for AND sustainable AND development AND geography). We limited the research period to 2015-2024, but there was no limit to the language and type of publication (except preprints). We exclude preprints in areas which are not related to higher education and geography on the basis of filtering the titles and abstracts of publications. As a result, 449 publications remained, which were classified by research areas (**Table 3**).

Table 1. Research areas of ESD and geography-related publications in 2015-2024 according to WoS

Field: WoS categories	RC	P (%)
Education and educational research	83	37.900
Green sustainable science technology	61	27.854
Environmental studies	59	26.941
Environmental sciences	54	24.658
Geography	33	15.068
Geography physical	10	4.566
Geosciences multidisciplinary	7	3.196
Economics	6	2.740
Education scientific disciplines	5	2.283
Remote sensing	5	2.283
Social sciences interdisciplinary	5	2.283
Computer science information systems	4	1.826
Hospitality leisure sport tourism	4	1.826
Public environmental occupational health	4	1.826
Computer science information systems	4	1.826
Hospitality leisure sport tourism	4	1.826
Public environmental occupational health	4	1.826
Business	3	1.370
Multidisciplinary sciences	3	1.370
Area studies	2	0.913
Biology	2	0.913
Computer science interdisciplinary application	2	0.913
Construction building technology	2	0.913
Development studies	2	0.913
Engineering civil	2	0.913
Engineering environmental	2	0.913
Engineering multidisciplinary	2	0.913
Geology	2	0.913

Note. RC: Record count & P (%): Percentage of 219

Table 2. According to WoS ESD in 2015-2024 and geography-related publications' provision of SDGs

SDGs	RC*	P (%)
04 Quality education	99	45.205
13 Climate action	47	21.461
09 Industry innovation and infrastructure	36	16.438
11 Sustainable cities and communities	36	16.438
15 Life on land	36	16.438
14 Life below water	35	15.981
02 Zero hunger	32	14.611
12 Responsible consumption and production	30	13.698
03 Good health and well-being	29	13.242
07 Affordable and clean energy	10	4.566
01 No poverty	7	3.196
05 Gender equality	7	3.196
06 Clean water and sanitation	7	3.196
08 Decent work and economic growth	7	3.196
10 Reduced inequality	7	3.196
17 Partnerships for the goals	1	0.456

Note. RC: Record count; P (%): Percentage of 219; & *Since some publications cover several fields, total number of publications/their contributions differ from initial number

Initial research on the key word "education for sustainable development and geography" in the dimensions database and formal filtering based on selected criteria were carried out on October 10-20, 2024.

Table 3. Research areas of publications related to ESD and school geography in 2015-2024 in Scopus database

Field	RC*	P (%)
Social sciences	314	69.933
Environmental science	161	35.857
Earth and planetary sciences	111	24.721
Computer science	66	14.699
Energy	61	13.585
Engineering	35	7.795
Medicine	35	7.795
Business, management, and accounting	25	5.567
Agricultural and biological sciences	24	5.345
Economics, econometrics, and finance	20	4.454
Arts and humanities	15	3.340
Psychology	15	3.340
Multidisciplinary	12	2.672
Other	36	8.017

Note. RC: Record count; P (%): Percentage of 449; & *Since some publications cover several fields, total number of publications/their contributions differ from initial number

Table 4. Results of filtering publications related to ESD and school geography in Dimensions database

	Stage 1	Stage 2	Stage 3
2024	1,017	1,002	731
2023	2,784	2,782	1,070
2022	2,427	2,426	965
2021	1,747	1,747	710
2020	2,411	2,411	698
2019	1,364	1,364	513
2018	808	808	427
2017	1,090	1,090	399
2016	518	518	337
2015	462	462	237
Other years	4,577	-	-
Total	19,205	14,610	6,087

Initial search results yielded 19,186 publications, publications published before 2015 and included in this list on the basis of only one key word were excluded in the 2nd stage of filtering, as a result, the number of publications was 14,610. During the 3rd stage, we excluded repeated publications that were totally unrelated to ESD and geography education, their total number was 6,087 (**Table 4**).

Figure 2 shows how the filtration in the identification phase was carried out.

Since the fields of research in Dimensions are based on the Australian and New Zealand standard research classification (Australian Bureau of Statistics, 2020), during the qualitative analysis, fields related to physical and social geography or describing modern teaching technologies (geoinformatics, artificial intelligence, etc.) were also considered. The process of data processing was implemented in the PRISMA 2020 flow chart proposed by Haddaway et al. (2022), as a result, 24 publications were selected (**Figure 3**).

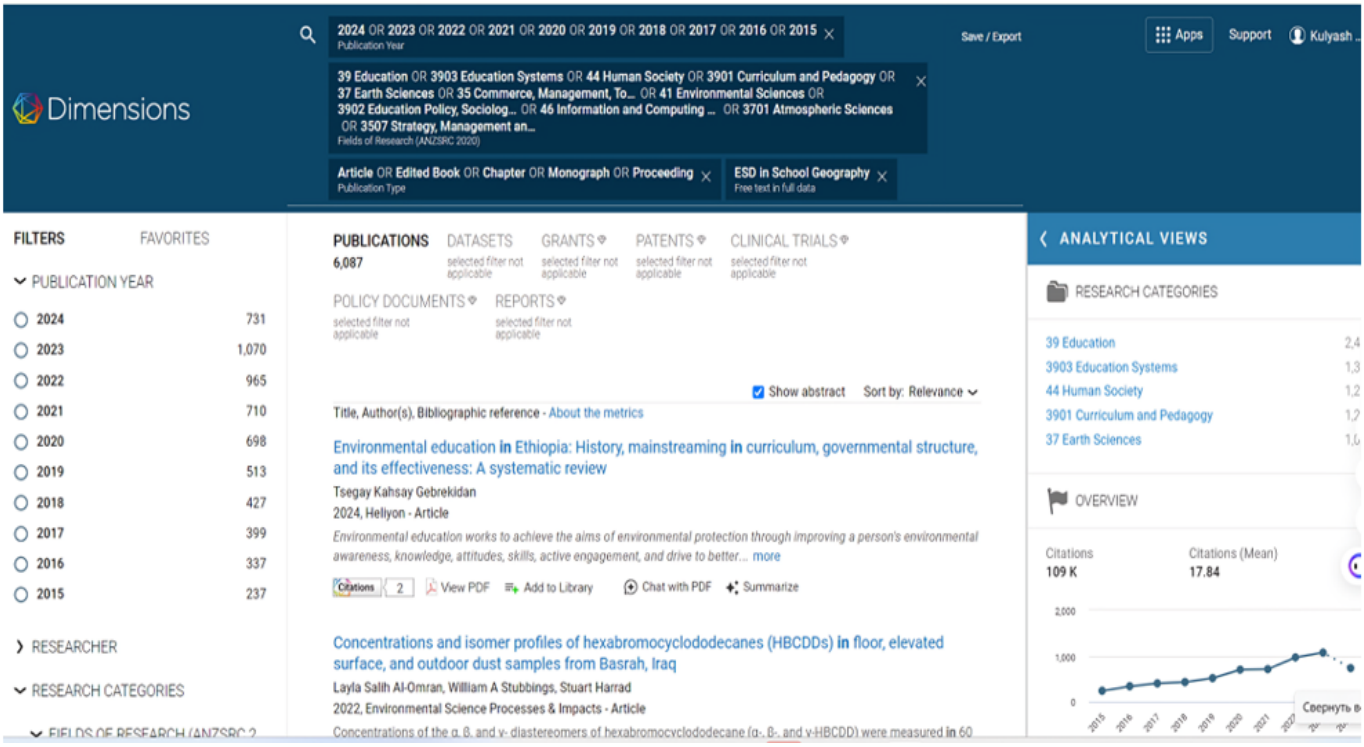

Figure 2. The result of the 2nd stage of the selection of publications according to the topic on the basis of Dimensions (Source: Authors' own elaboration)

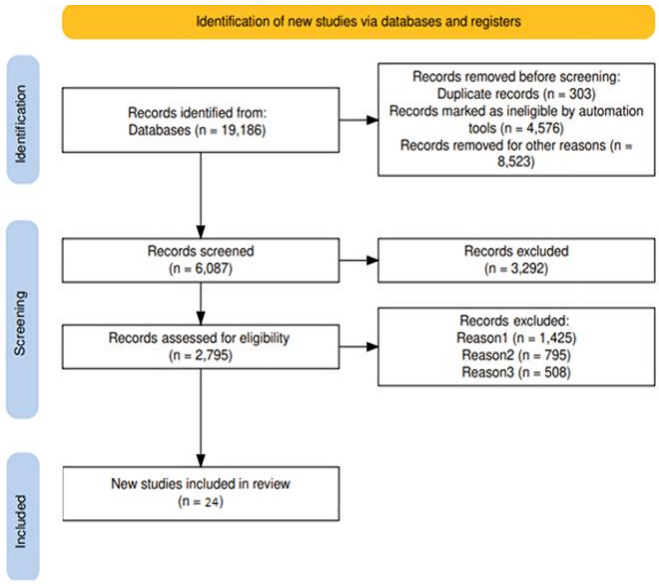

Figure 3. Flowchart of steps for identifying and screening publications related to ESD and school geography in Dimensions database (Source: Authors' own elaboration)

The resulting data was loaded into pivot tables using the possibilities in Dimensions database. This data was the basis for subsequent analysis and visualizations.

Methods and Tools of Analysis

In this study, we used a combination of analysis (statistical analysis, thematic analysis, and meta-analysis) and evaluation methods in order to reveal the current situation and opportunities for implementing ESD in school geography. It was determined that the aims of sustainable development were reflected, which country the authors are from and which research areas they are related to, materials of this analysis were compiled into Excel tables as a reference in the analysis of the publications.

Metadata related to the research topic was exported to an Excel file in the Scopus, Dimensions platforms, and then the data in Excel file was converted and loaded into the formats used in the bibliometric software VOSviewer (version 1.6.19) to create research maps. VOSviewer has been developed by Nees Jan van Eck and Ludo Waltman at Leiden University's Center for Science and Technology Studies. Bibliometric analyzes and visualization were performed using VOSviewer software on the basis of initial automatic selection results. We used the JavaScript object notation (JSON) text format to create a map on the basis of the network data in VOSviewer. We have noticed that it holds more information than other file formats and it can be integrated into VOSviewer without any errors. Key word map was created on the basis of this option. Maps of co-authors, coincidence of key words, making citations were compiled in VOSviewer's "mapping based on bibliographic data" option with the use of data from research information systems (RIS), xls, scv files.

To create a co-authorship map, you need to select the option on VOSviewer "create a map based on bibliographic data". The next step is to select the data source. For example, we selected the option "read data from bibliographic database files". The files of WoS,

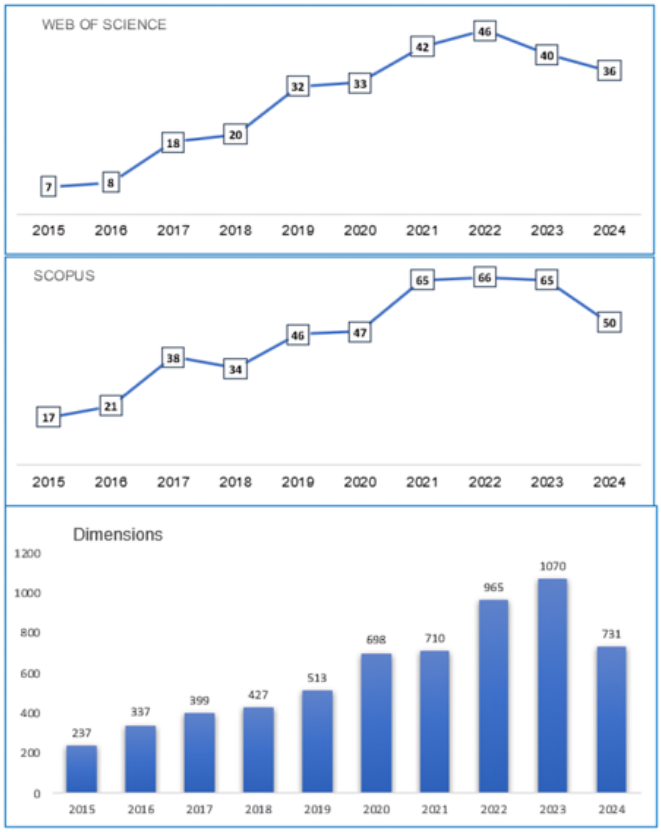

Figure 4. Dynamics of the number of publications related to ESD and school geography in scientific databases (Source: Authors' own elaboration)

Scopus, and Dimensions scientific databases that we selected for this review are compatible with this option. Then we selected the analysis type–"co-authors", the "full count" option was selected as the calculation method, and the authors were selected as the unit of analysis. For the number of authors we selected, the program will calculate the total strength of co-authorship links with other authors. Thus, in the end we will receive a map that will reflect the co-authors with the greatest total strength of links.

Citation information in RIS files include titles, authors, publishers, key words, issue numbers, etc., therefore it is often used in bibliometric mapping. The map of spatial distribution of publications was compiled with the use of ArcGIS 10.4 software. As the bibliometric and meta-analysis results revealed that the issue of introducing ESD in geography has not yet been fully studied, as a result of which, in some countries, there is a lack of educational content on sustainable development in school geography, a lack of knowledge and motivation of teachers to implement ESD, a lack of widespread dissemination of effective practices in the implementation of ESD. The results also reveal the prospect of increasing the potential of the subject in the implementation of ESD through the effective use of information and communication technologies in modern school geography, retraining of geography teachers in special advanced training courses.

RESULTS AND DISCUSSION

What Does the Bibliometric Map of ESD Study in School Geography Look Like?

We performed a bibliometric analysis of publications from WoS, Scopus, and Dimensions databases for the period 2015-2024 related to school geography and ESD integration in this review. Bibliometric analysis provided important information such as research areas, citations, key words, co-authors and cross-citations. This analysis showed that the number of publications in scientific databases during the mentioned period varied, but in general it has been increased every year (**Figure 4**).

The low number of publications in 2024, in **Figure 4** is explained by the fact that the year is not over. Having considered the incompleteness of this year's data, it can be seen that the number of publications in WoS database increased by 5.7 times in 2023 compared to 2015 and in Dimensions database by 4.5 times during the same period. This growth proves that researchers have increased interest in the issue of education in ESD in school geography and that geography subject has a high potential in this direction.

The data collected from the database using filters to text JSON file can be exported analyzing the key words in publications in Dimensions database. Visualization of these data in the VOSviewer software gave possibility to construct the map of key words in research related to ESD and school geography (**Figure 5**).

The most frequent key word "sustainable development" was in the publications of this direction on the map, which also differed in terms of creating connections with other key words. The key words "teaching geography", "covid", "climate change", "university", "child", "ESD", "lesson" are also extensive in terms of frequency of use and breadth of interconnections.

A Review of Prominent Research on Integrating ESD Into School Geography

Identification of outstanding researchers was carried out in several directions: the number of publications, the number of citations made to them, the number of "co-citations". For example, 2,844 citations were made to 207 out of 219 publications published in the period 2015-2024 under the key word "education for sustainable development and geography" in WoS database (**Figure 6**).

While the level of making citations to published works indicates an increased interest in research related to this area, on the other hand, it indicates that the number of publications is still very few.

Next, the spatial distribution of the collected data was analyzed. Data exported from databases were processed in different software (ArcGIS 10.4 and VOSviewer), maps were compiled.

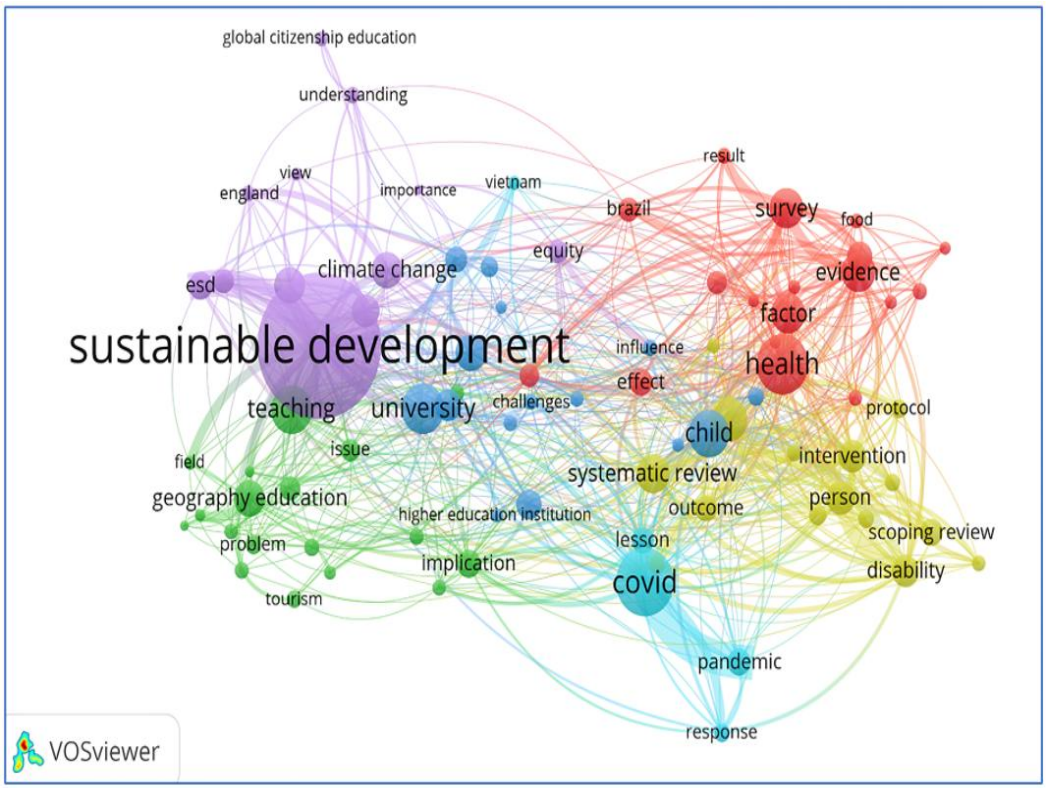

Figure 5. A map of key words in research related to ESD and school geography (Source: Authors' own elaboration)

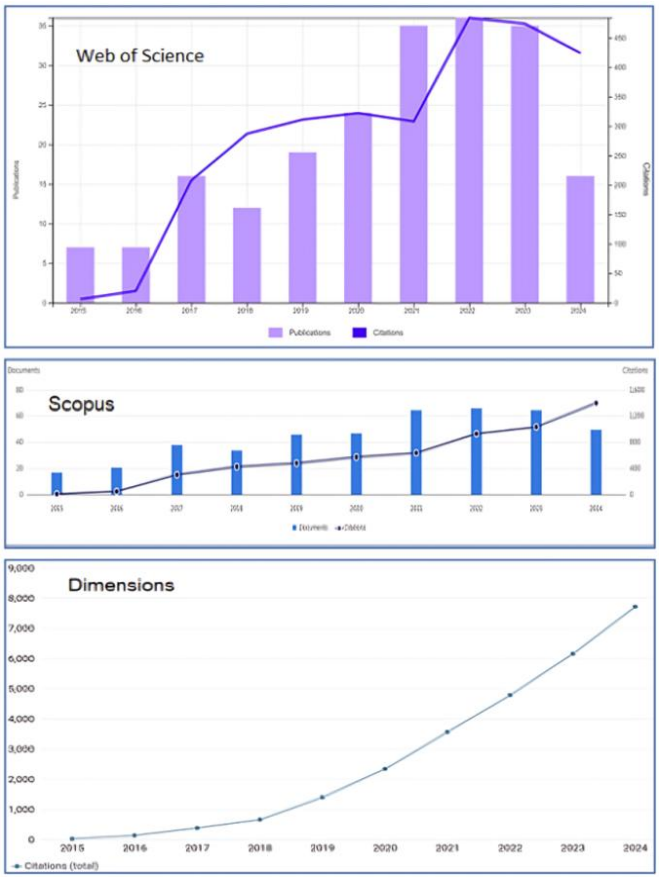

Figure 6. The citations published on "education for sustainable development and geography" (Graphs were created automatically by the corresponding platforms)

The map created in VOSviewer used data from the Dimensions database, which includes more universal editions and publications. In the constructed map, the nodes represent individual countries and their volume is represented by the number of publications or citations, thereby which countries have a specific weight according to ESD in geography is determined (**Figure 7**).

The highest level of activity in this direction is observed in Great Britain (387 documents, 16,708 citations, 496 total link strength), USA (280 documents, 12,754 citations, 405 total link strength) and Germany (225 documents, 9,378 citations, 377 total link strength). China ranks 4th in terms of number of researchers and references (203 documents, 7,378 citations), but 4th in total link strength (241) after Sweden. This can be explained by the relatively high international collaboration of Swedish authors. Lines connecting countries on the map indicate mutual collaboration (co-authorship, joint research projects or making references), and whether the lines are thick or thin indicates the level of these connections.

Spatial distribution of publications related to geographic education in the Scopus database in ESD related to country was depicted on a map created on the ArcGIS 10.4 platform. The analysis of these data shows that the research in this direction are conducted in 103 countries of the world and published in publications in the Scopus database, which reveals that the research have taken global feature (**Figure 8**).

The geographical distribution of publications showed that studies related to for sustainable

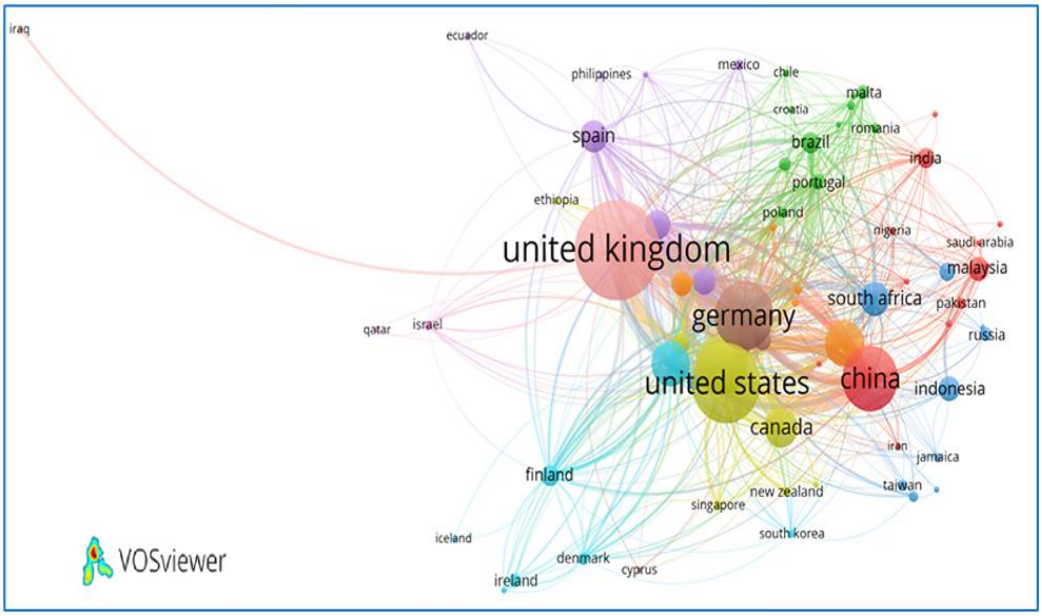

Figure 7. Map of the international cooperation network for the implementation of ESD in the subject of geography in 2015-2024 (Source: Authors' own elaboration)

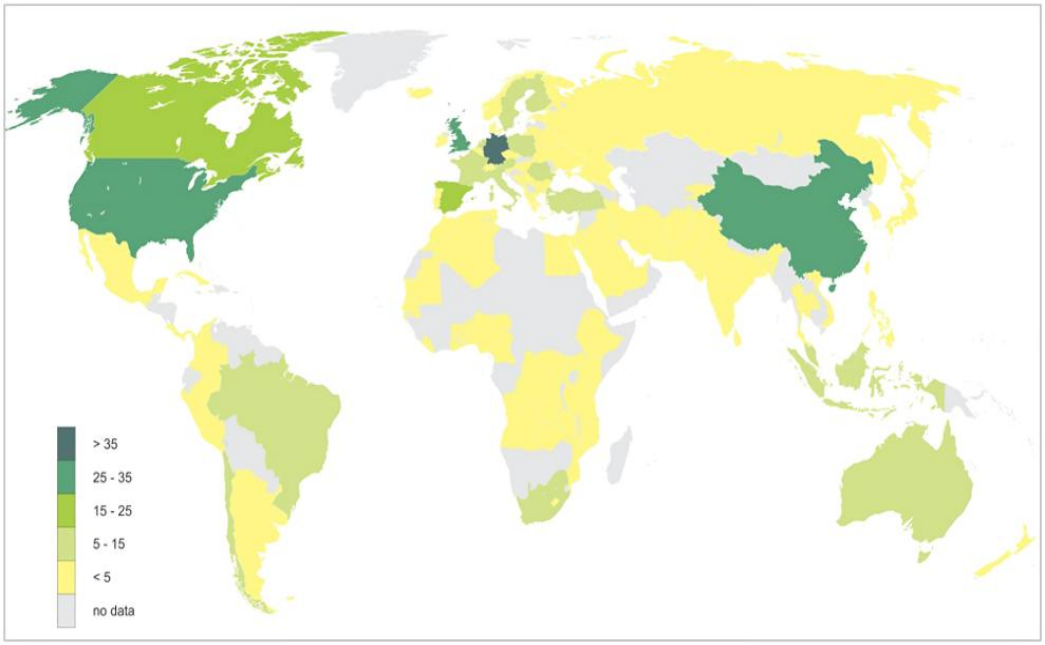

Figure 8. Spatial distribution of publications on the implementation of ESD in the subject of geography in 2015-2024 (n = 449) (Source: Authors' own elaboration)

development in the subject of geography are mainly concentrated in Germany (36), Great Britain (32), USA (29), China (27), Spain (20), Canada (15). 30% of the works published in this direction belong to the share of these countries.

The number of citations given to each publication gives the possibility to identify prominent authors, which is used to describe the analysis of citations performed in VOSviewer on the map. The analysis of author co-citations allows visualization of mutual similarities between authors doing research in the same direction. They are named together in referring to the works of such authors, which allows creating a network map of connections among authors. Cards of this kind give the possibility to identify outstanding scientists in a particular field.

The construction of the map in relation to the number of publications showed the leading authors in this direction. The large circles show the number of publications, the level of authors' networking through citations and collaboration among the authors of the publication in **Figure 9**.

In the author network map, the connectivity of researchers is determined based on the number of links to each other (**Figure 10**).

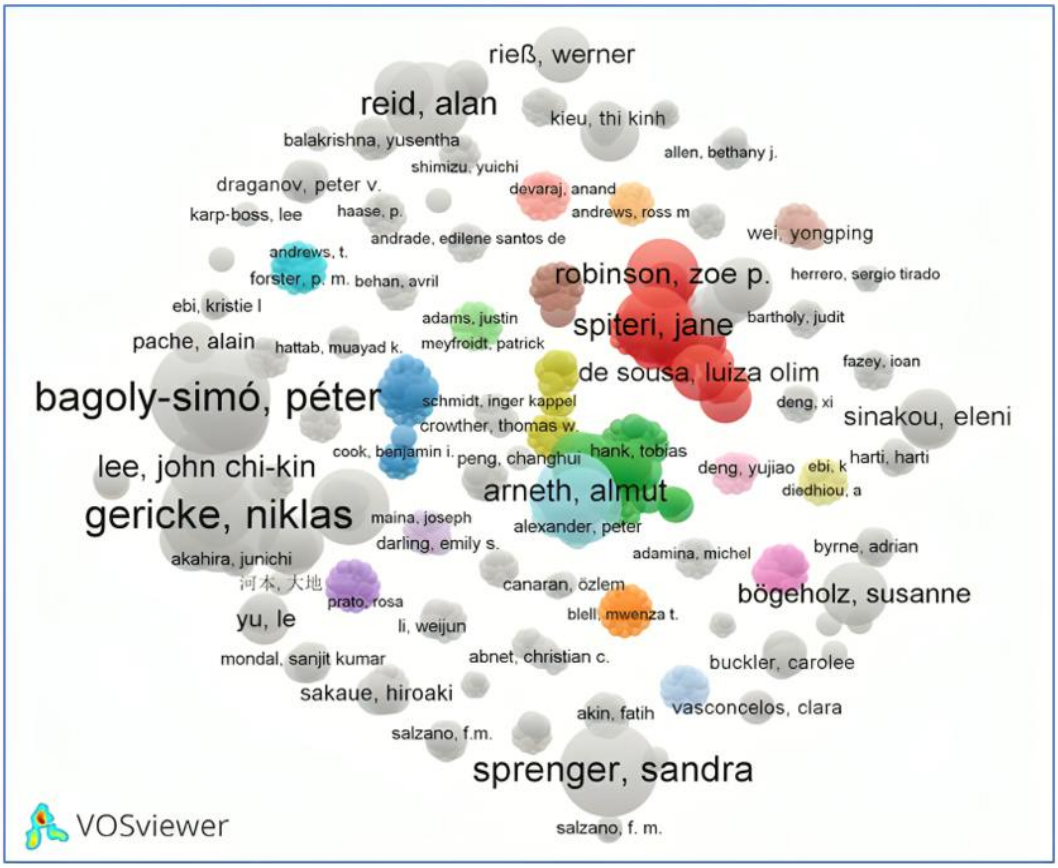

Figure 9. Map of the authors of the publication in the direction "education for sustainable development and geography" in Dimensions database (Source: Authors' own elaboration)

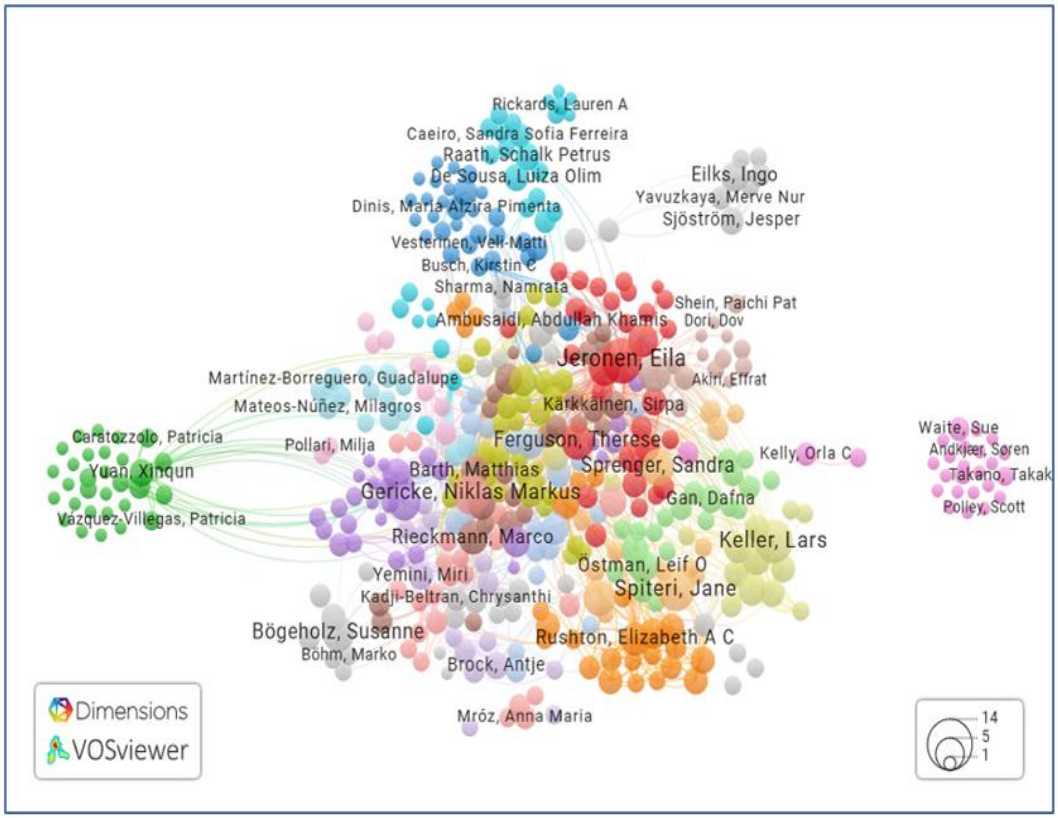

Figure 10. Map of the author network for "education for sustainable development and geography" (Source: Authors' own elaboration)

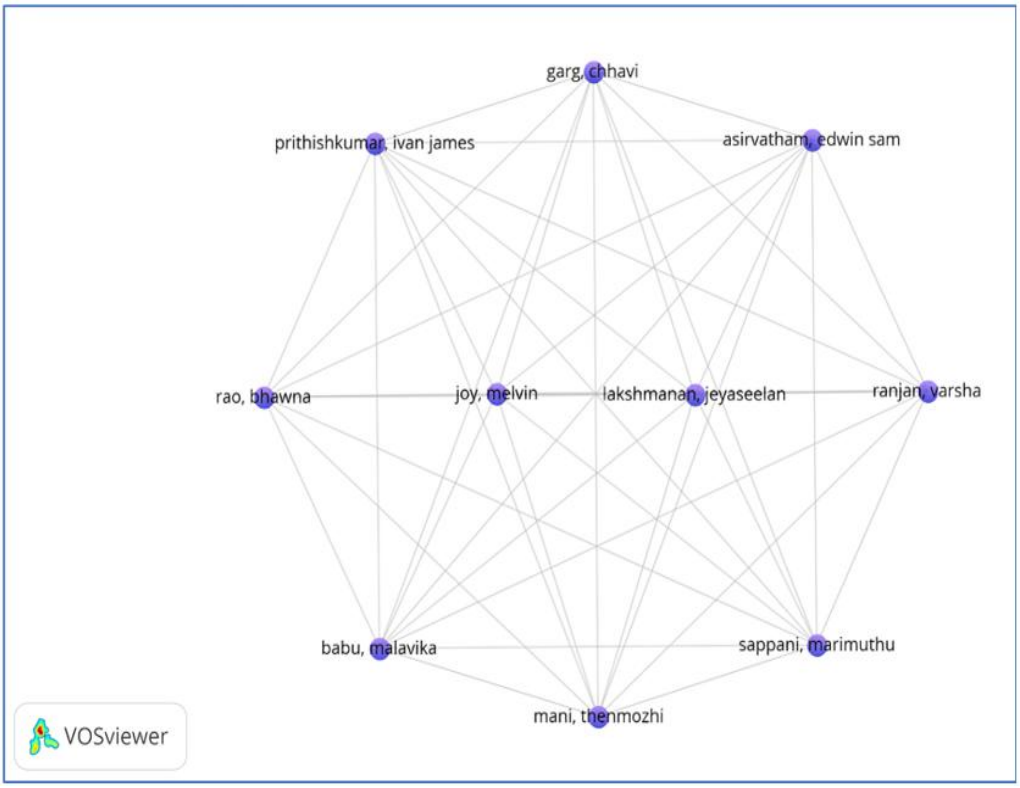

Figure 11. Map of the authors of the publication in the direction "education for sustainable development and geography" in Scopus database (Source: Authors' own elaboration)

The map shows publications by 441 researchers divided by their relationships into 23 clusters, each of which is designated by a specific color. The number of mutual citations is 2,971, and the total number of citations is 4,448.

Based on the csv file exported from the Scopus database, we created a co-authorship map in VOSviewer (**Figure 11**). For this map, we selected the analysis type "co-authors" and the calculation method "total number". This map reflects the leading co-authors with the highest total strength of connections.

However, we found that it is not sufficient to show this problem only through map details. In the next stage of the analysis, clarification of the authors' contributions to sustainable development and geographical knowledge was considered on the basis of data on the level of citations, not only the number of publications of each author. In general, not only was education in the direction of sustainable development in school geography included, but also the researchers who contributed to the creation of theoretical basis for the formation of that knowledge were included in the selection of outstanding authors (**Table 5**).

Table 5. Prominent authors of publications on ESD and geography

No	Author	Affiliation	Priority area	D	C	C-A
1	Almuth Arneth	Karlsruhe Institute of Technology, Germany	Climate change & ecosystem	423	43,892	1,549
2	Bo-Jie Fu	Research Center for Eco-Environmental Sciences, China	Geography, ecosystem, & sustainable development	750	40,831	-
3	Le Yu	Tsinghua University, China	Land, climate change, & sustainable development	80	12,517	764
4	Michael Edward Meadows	University of Cape Town, South Africa	Climate change, geography, & sustainable development	248	5,637	437
5	Yong-Ping Wei	University of Queensland, Australia	Sustainable development & ecosystem	49	4,156	275
6	Niklas Markus Gericke	Karlstad University, Sweden	Education, school, & ESD	104	3,146	190
7	John Chi-Kin Lee	Education University of Hong Kong, China	Education & secondary schools	207	2,871	167
8	Susanne Bögeholz	University of Göttingen, Germany	Teacher education & ESD	47	1,220	35
9	Alan D. Reid	Monash University, Australia	Environmental education & ESD	64	1,163	38
10	Zoe Patricia Robinson	Keele University, United Kingdom	Higher education & ESD	44	1,138	73

Note. D: Documents; C: Citations; & C-A: Co-authors

Table 5 (Continued). Prominent authors of publications on ESD and geography

No	Author	Affiliation	Priority area	D	C	C-A
11	Werner Rieß	University of Education Freiburg, Germany	Education, sustainable development, & ESD	40	736	31
12	Eleni Sinakou	University of Antwerp, Belgium	Education, sustainable development, & ESD teaching	11	324	15
13	Luiza Olim de Sousa	North-West University–Potchefstroom, South Africa	Environmental education & ESD	18	317	53
14	Jane Spiteri	University of Malta, Malta	Childhood education & ESD	36	251	29
15	Péter Bagoly-Simó	Humboldt University of Berlin, Germany	Geography, education, & ESD	52	224	50
16	Sandra Sprenger	University of Hamburg, Germany	Geography, education, & ESD	19	112	59

Note. D: Documents; C: Citations; & C-A: Co-authors

Almuth Arneth (Germany), Bo-Jie Fu and Le Yu (China), and others are among the leaders in terms of the number of these publications and making references.

On the basis of the indicators of citation to their publications, it can be said that these scientists study modern sustainable development issues on the basis of natural sciences and create theoretical basis for ESD.

Current State and Technologies of Implementation of ESD in School Geography

At present, there are articles in various directions among the publications. However, it was considered that important studies of researchers were in the direction of environment, certain issues of sustainable development (climate change, water, land resources, ecology, etc.), geographical education. In general, ESD implementation methods and recommendations have been analyzed by researchers (Mochizuki & Bryan, 2015; Riess et al., 2022; Tiwary, 2023). However, without reliable indicators, macro- and meso-level analysis of ESD implementation remains insufficiently detailed and this requires a shift to micro-level evaluations that measure outcomes related to sustainability knowledge, skills, attitudes, values and behaviors (Waltner et al., 2018). This perspective is coincided with the conceptual framework that emphasizes the development of ESD learning environments that promote meaningful learning experiences and encourage critical thinking (Sinakou et al., 2019).

Fu (2020) justified the close connection of sustainable development with geography and need to use the potential of geography to study the relationship between society and environment spatially to promote sustainable development. Indeed, equipping learners with geographic knowledge to achieve sustainable future is one of the main contributions of geography as a school subject to the education of young people, however there is a gap between the possibilities of geography for ESD and its full use in practice (Bagoly-Simó, 2023; Bagoly-Simó & Kriewaldt , 2022).

Undoubtedly, these studies provide a theoretical basis for the implementation of ESD in school geography. Because the subject of geography is very suitable for the study of sustainable development concepts and environmental protection issues, it is fully coincided with the implementation of the principles of sustainable development (Lindau & Kuckuck, 2022). The authors consider that geography education can play an important role in achieving SDGs by developing learners' critical thinking and interdisciplinary connections.

Geography can help students develop critical thinking about an interconnected world by explaining its own spatial history, the world's connections and their consequences, as the planet is constantly changing.

Through the explanation of ever-changing planet`s spatial history, the world's connections and their consequences in the study of geography, learners can develop critical thinking about an interconnected world. It has been noted that coinciding geography curriculum with ESD principles is important to promote a comprehensive comprehension of sustainable development among learners (Guo et al., 2018). This opinion is also agreed by the researchers who emphasized the potential of development of sustainable development competence through the systematic approach in the development of geographic education curriculum (Miao et al., 2022). As studies have revealed, current geography curricula in various countries emphasize memorization and listing of facts instead of critical thinking and problem-solving skills required for ESD. For example, many geography textbooks in Vietnam have been found to focus on memorizing rather than developing ESD competencies, it means ESD is often considered as an additional topic rather than an integral component of the curriculum (Nguyen, 2019).

In addition, results taken from various studies indicate that continuous professional development of geography teachers is essential to ensure that they have the knowledge and skills needed to effectively teach ESD (Pasang & Najib, 2022). The need for adequate training in ESD principles for effective implementation of geography teachers in teaching practice is also emphasized (Ma, 2024; Nkonde et al., 2020).

In addition to knowledge and teaching skills, geography teachers need to develop a positive attitude towards ESD. As studies have revealed, many teachers express a positive attitude towards introducing

Table 6. Comparison of review articles on education for sustainable development in geography

Data publication	Main direction of research	Methodology	Main results and contribution
Agbedahin (2019)	Sustainable development, ESD, & sustainable development agenda 2030	Literature review on the topic	The perspectives of sustainable development, ESD, implementation of the agenda are offered as a result of the classification analysis of the publication.
Hallinger and Nguyen (2020)	Mapping the landscape and structure of ESD research	Systematic bibliometric review	Mapping based on a bibliometric review of 1,842 publications on ESD in K-12 schools and recommendations for research perspectives are given in this review.
Kolleck et al. (2017)	The importance of social networks in climate change education and ESD implementation	Review of sources	The influence of different participants on the implementation of knowledge about ESD and climate change is analyzed. Climate change knowledge indicators and data from Twitter, its own surveys are used in the study.
Lorente-Echeverría et al. (2022)	Sustainability in primary school teacher training programs	A systematic review of the literature	The literature in ERIC, WoS, Scopus, and other databases is systematically analyzed, and recommendations for improving primary school teacher training programs are based.
Current research	Implementation of ESD in geography	Bibliometric analysis (2015-2024)	The directions of research on the introduction of ESD into the subject of geography, the leading authors have been identified. Research data were analyzed and mapped in ArcGIS 10.4 and VOSviewer software.

sustainability issues into the curriculum, they often face challenges related to training and resources (Peedikayil et al., 2023). This highlights the importance of creating an enabling environment for teachers to share the best practices and collaborate on ESD initiatives.

In addition, a number of studies reveal the need to coincide geographical education with SDGs, thus the relevance of ESD is increased in current educational contexts (Hawa et al., 2021). Assessing geography teachers' competence in ESD is important to identify areas for improvement and ensure effective implementation. Studies of geography teachers' self-perceived competencies show significant discrepancies between teachers' perceived abilities and expectations of educational standards (Osuch, 2011). This deficiency highlights the need for ongoing professional development and reflective practices that encourage teachers to critically evaluate their ESD competencies.

A comparison of our study with previously published similar studies shows the innovative nature of the approach we used and the results we have obtained (**Table 6**).

The comparison of important aspects and results of previous studies with the current study was systematically presented in **Table 6**. The innovative feature of the research is determined by the visualization of the research in the direction of introduction of ESD into the subject of geography with modern analytical tools and direction of future research.

Geography studies the interactions between human societies and their environments, making it an important subject for the effective implementation of ESD principles. Integrating ESD into geography teaching is particularly relevant given pressing global issues such as climate change, environmental degradation, and social inequalities. Sánchez et al. (2020) point to the historical connection between geography and sustainable development, arguing that geography serves as a foundational discipline for ESD due to its holistic approach to understanding the relationships between nature, economy, and society.

The literature highlights various pedagogical approaches and technological advances that can enhance the teaching of ESD in geography education. One of the main methods for teaching ESD in geography is project-based learning (PBL), which encourages students to interact with local communities and environments. This approach not only promotes a deeper understanding of sustainability issues but also fosters active citizenship among students. Yli-Panula et al. (2019) highlight that PBL can generate public interest and motivate local decision makers to integrate sustainability into educational programs, thereby increasing the relevance of geography education in solving real-world problems.

The introduction of geographic information systems (GIS) into geography education has been identified as a powerful tool for promoting ESD. GIS enables students to analyze spatial data and visualize complex environmental issues, thereby enhancing their understanding of sustainability concepts. Angiel and Pokojski (2019) argue that GIS applications facilitate the linking of facts and data from different sources, which is crucial for understanding spatial interactions in the geographic environment. For example, the use of web-based GIS in high school geography education enables dynamic monitoring and analysis of natural disasters, an important aspect of ESD (Li et al., 2022). This technological integration not only aids learning but also enables students to develop data-driven decision-

making skills related to sustainability. Similarly, Hwang (2013) discusses how GIS can be integrated into sustainability education, suggesting that it allows students to explore sustainability issues through spatial exploration, thereby promoting critical thinking and analytical skills. Blended learning approaches that combine traditional face-to-face teaching with online learning have also been identified as effective in promoting ESD.

Leininger-Frézal et al. (2023) note that blended learning can facilitate a more flexible and personalized learning experience, allowing students to engage with ESD content at their own pace while benefiting from collaborative learning opportunities. This method has been found to be particularly effective in higher education, where students can access a wider range of resources and engage in discussions that enhance their understanding of sustainability issues.

It is noteworthy that the use of mobile learning technologies has become a significant trend in geography education. López and González (2020) highlight that outdoor learning supported by mobile devices and geospatial technologies allows learners to interact with their physical and social environment in a meaningful way. This hands-on approach not only increases engagement but also allows for the collection of real-time data that can be used to address local sustainability issues. The combination of mobile learning and GIS tools creates a dynamic learning environment that promotes understanding of complex sustainability issues. The role of technology in ESD is further highlighted by the application of virtual reality (VR) in geography teaching. Feng and Cao (2019) advocate the integration of VR technology to develop core competencies in geography, arguing that immersive experiences can significantly enhance learners' understanding of regional economic development and sustainability. This innovative approach not only engages learners but also provides them with a unique perspective on geographic phenomena, thereby enriching their learning experience. Niu et al. (2023) noted that the use of VR in geography lessons promotes the implementation of situated learning. We believe that situated learning is effective in developing students' ESD competencies because the sustainable development content is based on practice. This further proves the effectiveness of VR in teaching geography. Czimre et al (2024) as a result of an extensive systematic review of literature on this topic concluded that the use of VR technology is an effective and useful way of teaching geography.

Another tool for successful ESD in geography is the technological pedagogical content knowledge model, which emphasizes the integration of technology, pedagogy, and content knowledge. Álvarez-Otero and De Lázaro y Torres (2018) suggest that using WebGIS to visualize indicators related to SDGs can promote a deeper understanding of these global issues among students. This model encourages educators to take a holistic approach to teaching geography, ensuring that sustainable development concepts are integrated into the curriculum.

For the successful implementation of ESD in geography and the creation of sustainable learning environments, it is important for teachers to have the necessary skills and knowledge. Bertschy et al. (2013) point out the need for teachers to develop competencies that will enable them to effectively deliver ESD learning content, emphasizing the importance of professional development and interdisciplinary collaboration. Teachers' self-efficacy beliefs regarding ESD are also crucial as they influence the successful implementation of ESD in the classroom (Handtke et al., 2022). Concerted efforts have been made to integrate ESD into geography curricula in different countries, including Turkey and Germany (Barak & Avcı, 2022), Spain and China. Crespo Castellanos et al. (2021) discuss trends and prospects for ESD in Spanish geography education, noting the challenges and opportunities arising from this integration. Similarly, Guo et al. (2018) highlight the importance of geography education in China for understanding sustainable development, emphasizing the need for curriculum reforms that are aligned with ESD principles. These examples show global recognition of the importance of ESD in geography education and the different strategies used to implement it.

Overall, the technology of teaching ESD in geography encompasses a range of innovative pedagogical approaches and technological tools that enhance students' engagement in understanding sustainability issues. The integration of PBL, GIS, mobile learning and VR technology, as well as sufficient teacher training, provide a comprehensive strategy for promoting ESD in geography classrooms. As global issues continue to evolve, the role of geography education in promoting sustainable development becomes increasingly important, requiring ongoing research and collaboration between educators and researchers.

CONCLUSION

Studies related to the potential of contemporary school geography and ESD in the scientific databases WoS, Scopus, and Dimensions were bibliometrically analyzed as a result of the study. As a result, the dyna mics of research in this direction and map of key words in them were compiled.

As a result of a review of advanced studies on the integration of ESD into school geography, maps of the spatial distribution of publications published in this direction in 2015-2024, the international collaboration network of research and authors of publications have been compiled with the use of software tools (ArcGIS

10.4 and VOSviewer), a summary table of visual authors was created in this field.

Analysis of the current state of ESD implementation in school geography has defined that there are obstacles in sufficiently fulfilling the mission of geography as a leading subject in the promotion of ESD. Future research on the implementation of ESD in the subject of geography should be aimed at fully using the potential of geography, considering current educational trends. In future, we consider that the educational content of the subject of geography, integrating with related subjects research in the following directions is necessary to coincide with the aims of sustainable development and introduce effective teaching methods:

1. *The use of artificial intelligence, VR-technologies in the implementation of ESD in geography*. This provides attractiveness, accessibility and understanding of geography. We consider that experimental studies in this direction are very important in increasing the effectiveness of the subject of geography in teaching sustainable development.
2. *Using the interdisciplinary connections of geography to teach sustainable development*. The main idea of research in this direction is to introduce the experience of transforming natural science and social knowledge into a unified system of knowledge about the world, thereby forming a personality that ensures the stability of the world.
3. *Substantiating the transformation of geography curricula in accordance with educational levels and considering local natural, socio-cultural features*. Curriculums are changed only as a result of extensive research, therefore, it is essential that the content of education is based on sufficient research in terms of the theory of geography and teaching methodology.

Limitations of the Study

Despite documenting and identifying key publication trends on the topic, a bibliometric analysis covering three broad scientific databases for reviewing publications does not focus on the findings presented in the analyzed publications. Such a study has its limitations: there are technical limitations in compiling bibliometric maps based on the combined data of WoS, Scopus, and Dimensions. There are also duplicate publications in two or even three databases and inconsistencies in file formats, so we recommend paying attention to technical issues for future research in this direction. Another limitation of our study is the unequal analysis of publications from the three databases. It is important to note that scientific databases are updated quickly, so we recommend that future studies also include additional visualization methods, such as mathematical modeling, etc. Based on the above, we ask our readers to interpret our results considering these limitations.

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