Revista Românească pentru Educație Multidimensională
ISSN: 2066-7329 | e-ISSN: 2067-9270
Abstracting & Indexing | Clarivate Analytics - Web of Science (WoS); EBSCO; Google Scholar; ICI Journals Master List - Index Copernicus; Ideas RePeC; Econpapers; Socionet; CEEOL; Philpapers; KVK; WorldCat; CrossRef; J-GATE

2025, Volume 17, Issue 4, pages: 669-689 | https://doi.org/10.18662/rrem/17.4/1074
Submitted: October 13, 2025| *Accepted for publication:* November 25, 2025

Exploring Sustainability in Science Education: A Bibliometric Analysis of Web of Science (WoS) Data

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Abstract: *This bibliometric analysis study aims to identify, analyze, and discuss the current trends and thematic structures within the literature of sustainability in science education indexed in Web of Science (WoS) database from the first mention of the term through mid-2025. Therefore, the study focuses on a comprehensive bibliometric analysis and offers a discipline-specific systematic mapping of publication trends, influential scholars, and thematic structures in science education research. A total of 154 peer-reviewed articles were analyzed through three-stage process combining descriptive, network-based, and qualitative thematic analysis. First, descriptive bibliometric indicators which include publication trends by year, journal- and country-level distributions, and the most cited studies and authors were examined. Findings revealed a consistent upward trajectory in publication activity since 2007, with a sharp acceleration after 2018. It reflects the influence of the United Nations' Sustainable Development Goals (SDGs) on research agendas. The Sustainability journal emerged as the most leading journal, while the United States and Germany in country categorization led in national contributions. Second, keyword co-occurrence and thematic analyses highlighted core conceptual clusters centered on sustainability, climate change, biodiversity, and citizen science, as well as methodological strands focusing on program development, pedagogical approaches, and technological applications. Third, the categorization of publication types showed that the field is equally shaped by implementation-based interventions and review studies, while research on teachers and teacher candidates remains underrepresented. This study provides a field-specific synthesis of how sustainability has evolved within science education research and underscores the need for broader database triangulation and deeper theoretical engagement in future research.*

Keywords: *sustainability, science education, bibliometric analysis.*

How to cite: Özergun-Köse, I., & Beyazbal, S. (2025). Exploring sustainability in science education: a bibliometric analysis of web of science (WoS) data. *Revista Românească pentru Educație Multidimensională*, *17*(4), 669-689. https://doi.org/10.18662/rrem/17.4/1074

Introduction

The sustainability concept has become a critical point in education in the past decades. Sustainability education aims to prepare students to think critically, act responsibly, and contribute effectively to a sustainable future. (Sterling, 2010) Sustainability education has a critical importance in education, due to the global environmental problems in the World in the 21st century (Wals & Jickling, 2002). By the way, science education becomes as an important domain for embedding sustainability education because of its crossing terms and concepts (UNESCO, 2017). Because of the interdisciplinary nature of sustainability concept, science education provides a unique environment to integrate scientific knowledge with real-world contexts, enabling students to try to solve real world problems such as climate change, biodiversity loss, and resource depletion (Summers & Turner, 2011). According to the recent science education literature, numerous studies have indicated that integrating sustainability into science education significantly improves students' understanding of environmental challenges (Feinstein et al., 2015), increases environmental awareness (Feinstein et al., 2015; Zoller, 2012), and supports the development of sustainability awareness (Tytler, 2012).

Furthermore, bibliometric analysis has emerged as an effective method to systematically map and evaluate research trends, thematic evolutions, and collaborative patterns in academic disciplines (Donthu et al., 2021). Although bibliometric analysis studies have either examined sustainability or science education previously, their focus differs from the present study. For example, Hallinger & Nguyen (2020) conducted a bibliometric analysis to education for sustainable development (ESD) across general education. Their study emphasized publication trends and institutional collaborations up to 2018. In addition, Wang et al. (2024) analyzed climate change related research from 2000 to 2022 in their bibliometric analysis. Their focus was on global thematic evolution and scientific collaboration networks across multiple disciplines rather than science education specifically. In contrast, the present study provides a more recent and discipline specific synthesis by investigating sustainability in science education research. The analysis term was started from the first mention to mid-2025. This focus is particularly relevant and new because sustainability concepts such as environmental protection, energy conservation, and human–nature interaction are central themes of contemporary science education research and curriculum (Feinstein & Kirchgasler, 2015). By using data from globally recognized database called

Web of Science (WoS) (Zhu & Liu, 2020), this study aims to identify, analyze, and interpret how sustainability conceptualized, operationalized, and thematically used in science education research. In addition to that, the study integrates both descriptive and thematic bibliometric analysis with qualitative categorization of publication types. This approach helps the methodological scope of bibliometric studies in science education and provides valuable insights for guiding future sustainability in science education literature.

Literature review

Sustainability can be defined as an awareness that meets today's needs, without compromising the ability of future generations to meet their own needs (Giovannoni & Fabietti, 2013). Therefore, sustainability has become an important concept in educational research, particularly in the face of global challenges including climate change, biodiversity loss, and using resources economically (Green & Somerville, 2014). For this reason, in science education, sustainability is not only a scientific concept but also as a multidisciplinary framework that integrates environmental, social, and economic dimensions (Feinstein & Kirchgasler, 2015). This framework enables students to develop critical thinking, problem-solving, and decision-making skills for becoming future citizens who have sustainability awareness. As the role of science education in fostering a sustainable future gains significance, the concept of ESD has emerged as a guiding framework that links sustainability principles with teaching and learning processes across science education research (Boeve-de Pauw et al., 2015).

From science education topics and concepts such as climate change, biodiversity loss, or water literacy, there is an increasing awareness in the science education community of the need to support students in developing the knowledge, skills, and values for developing sustainability awareness for the future (Zoller, 2012). Previous research has shown that integrating environmental topics and sustainability concepts into science education enhances students' sensitivity to nature, social responsibility, and cooperative problem-solving abilities (Benner et al., 2017). Also, a recent empirical study demonstrated that integrating sustainability in science education not only improves environmental awareness but also develops socially responsible students. Therefore, sustainability is a lifelong value, it is critical to develop awareness of the environment, improve empathy, and conserve resources for science learners. More importantly, the successful integration of these values depends not only on science curriculum concepts but also on the attitudes and practices of science education research (Wilks, 2015). Previous empirical studies demonstrated that sustainability can be integrated into science education curriculum via different teaching methods. For example, using socio-scientific issues based science teaching including climate change, biodiversity loss, energy transitions, and water management enhance students' capacity to connect scientific concepts with decision making process (Burmeister et al., 2012).Therefore, socio-scientific issues based science teaching approach allows students to critically evaluate scientific evidence and propose contextually relevant solutions to sustainability related problems in real life (Sadler, 2011). Also, other recent science teaching methods, other recent science teaching methods such as inquiry-based learning, problem-based learning or project based learning have been shown to increase students' awareness related to sustainability concepts since using real world sustainability problems. (Shaby et al., 2021). Furthermore, interdisciplinary STEM (Science, Technology, Engineering, Mathematics) education and projects have been identified as effective strategies for linking scientific knowledge to sustainability related concepts, by trying to solve environment related problems that are faced in real or daily life (Alsop & Bencze, 2014). All of these science teaching methods not only deepen conceptual understanding of sustainability but also play a critical role in developing awareness related to sustainability through inquiry-based learning, problem-solving strategies, and socio-scientific issues which are increasingly recognized as essential for conceptual science education (Rieckmann, 2018).

Nowadays, most of the science education research related to sustainability focused on sustainable development goals (Dönmez, 2024), climate change (Garcia-Vinuesa, 2024; Trott & Weinberg, 2020), global warming (Gayford, 1995), marine education (Imaduddin, & Wilks, 2024; Mokos et al., 2020), citizen science (Lüsse et al., 2022; Sa et al., 2022), or green chemistry (Li & Eilks, 2021; Linkwitz & Eilks, 2022). In addition to that, bibliometric analysis research in the literature has begun to focus on topics related to sustainability. For example, Dönmez (2024) analyzed sustainability research in general educational disciplines, showing a shift from traditional environment education toward integrated sustainable education aligned with sustainable development goals, increases from the United Kingdom, Germany, and the USA. Similarly, Wang et als' (2024) bibliometric review of climate change education emphasizes its growing presence in science education literature but only focuses on climate change topics. In addition, biodiversity education has also been mapped by bibliometric analysis research, revealing increasing research output and highlighting key country clusters, such as the USA, China, and Germany (Derman, 2023).

To date, there has been limited research examining sustainability in science education through literature reviews or bibliometric analyses (Dönmez, 2024). Existing studies collectively underscore the need for a focused bibliometric investigation that explicitly addresses sustainability within science education, examining publication trends, influential authors and countries, and thematic patterns in keywords (Derman, 2023; Wang et al., 2024). Therefore, the purpose of this bibliometric analysis is to provide a comprehensive review of how sustainability is presented in science education research in peer-reviewed journals indexed in the WoS database, spanning from the earliest appearance of the term to mid-2025. The guiding research question of this study is: “How is sustainability in science education research represented in education literature through a bibliometric analysis?”

Methodology

Research design

Bibliometric analysis is a quantitative research design used to trace developments in a research topic that cannot be reviewed manually because of large datasets (Ellegaard & Wallin, 2015). It is a useful tool for visualizing major and emerging themes and offering researchers a foundation to identify literature gaps. However, due to the volume of data analyzed, bibliometric studies provide a broad overview rather than in-depth insight, unlike systematic reviews (Donthu et al., 2021). The aim of the study is to investigate the trends, research networks, and prominent themes in scientific publications on sustainability in science education through bibliometric analysis.

Data collection

The data were retrieved from publications on sustainability in science education indexed in the Web of Science (WoS) database in July 2025. The keyword phrase is applied *TOPIC: (sustainable* OR "sustainable development" OR "education for sustainable development" OR ESD) AND TOPIC: (science education OR "science teaching" OR "science learning")* in line with the purpose of the study. The search achieved a total of 222 publications. All publications were reviewed by the researchers. Those outside the scope were excluded and 154 publications were used in the analysis.

Inclusion and exclusion criteria

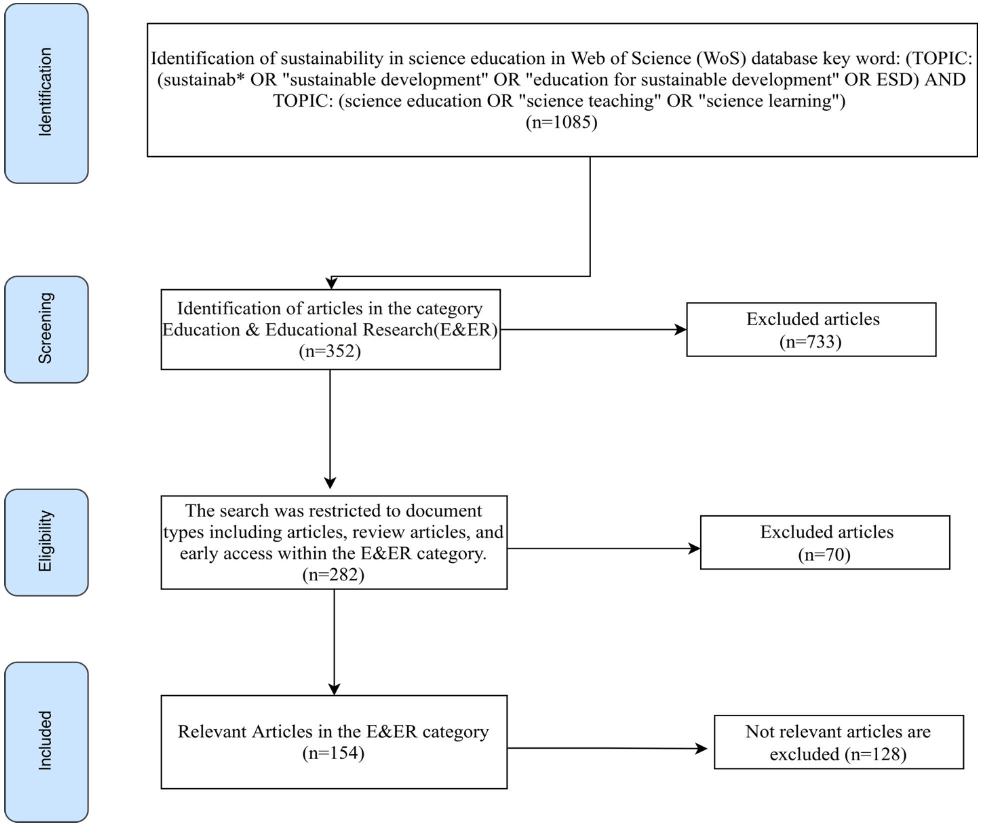
The inclusion and exclusion criteria were determined by using the PRISMA flow diagram (Moher et al., 2009) in the study. PRISMA flow diagram was originally developed for systematic reviews. Recent research demonstrates that it can also be applied in bibliometric studies to ensure methodological transparency and reproducibility (Pham & Lee, 2024). The PRISMA framework allows researchers to clearly present how records are identified, screened and selected which is particularly valuable to analyze large-scale databases. By illustrating the step-by-step filtering of data, the PRISMA approach enables prevent duplication, clarify inclusion boundaries and increase the traceability of bibliometric datasets (Malhotra, 2024). In this study, first, the included and excluded articles were identified from the WoS system within the *Education and Educational Research*(E&ER) category. In addition, the studies to be included were limited to articles, reviews, and early access articles. Studies in the form of books and book chapters were excluded.

Figure 1 presents the PRISMA flow diagram for the bibliometric review, including its four stages and processes. In the *identification stage*, the keyword specified below was searched by the researchers in the Web of Science (WoS) database:

"TOPIC: (sustainable OR "sustainable development" OR "education for sustainable development" OR ESD) AND TOPIC: (science education OR "science teaching" OR "science learning")*

No starting year was selected for the study, and the ending year was set as 2025.As a result of this stage, 1,085 studies were identified. In the *screening stage,* filtering by *Education & Educational Research* (E&ER) resulted in 352 articles being identified, while 733 articles were excluded. In the *eligibility stage*, filtering for articles, review articles, and early access led to the inclusion of 282 articles, while 70 articles were excluded. In the *included stage*, the 282 studies identified in the eligibility stage were reviewed by the researchers, and 128 irrelevant articles were excluded, resulting in 154 articles being included in the study.

Figure 1: Article Selection Process using Prisma Flow Diagram



Data analysis

For the bibliometric analysis, 154 publications determined through the PRISMA flow diagram from the Web of Science (WoS) database were used. These publications were uploaded to VOSviewer as a file. The analyses focused on three stages. In the first stage, the trends of the studies by year, the top five journals, country trends, and the most influential studies and researchers were analyzed. In the second stage, it was focused on keyword and theme analyses. A keyword co-occurrence analysis was conducted viaVOSviewer to map the conceptual structure of the research. A thematic analysis of abstract terms was applied to capture the broader research orientations. In the final stage, all publications were reviewed by the researchers, and the publication types were analyzed and categorized. The stage enabled the identification of the main target groups, educational levels, and methodological approaches employed in the publications.

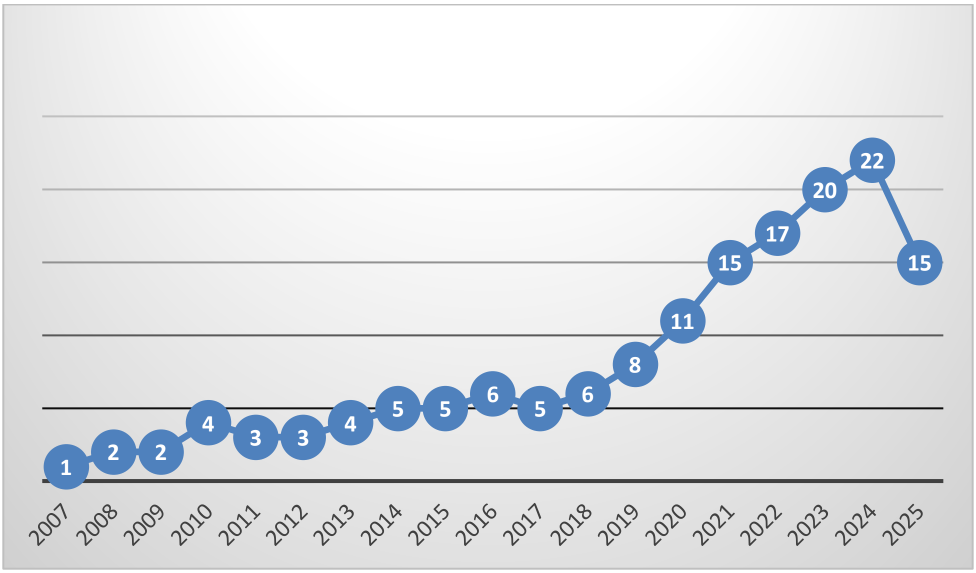
Findings

In line with the inclusion and exclusion criteria determined through the PRISMA flow diagram for the study, a total of 154 articles were included in the analysis. The findings are presented according to the three stages followed. In the first stage, the distribution of the articles by year was examined to reveal trends in the field. Analyses were conducted on research trends by year, the top five journals, country-level publication trends, and the most influential studies and researchers. In the second stage, data were used to examine keyword analyses and theme analyses. Through this process, the conceptual domains on which the research topics focused and the network relationships among studies were identified. In the third stage, qualitative content analysis was conducted to determine themes related to science education, and these themes were classified to reflect trends in the field.

Descriptive trends and publication characteristics

As shown in Figure 2, there has been a steady upward trend in sustainability-focused research within science education from 2007 to 2025. Although a steady increase can be observed over the years, there has been a marked acceleration in the upward trend since 2018. While the 2025 data show a slight decline, it should be noted that this figure reflects only the first half of the year, and the number of studies has already approached the total output of 2024. Therefore, it is assumed that this upward trend will continue by the end of 2025.

Figure 2: Annual Publication Trends



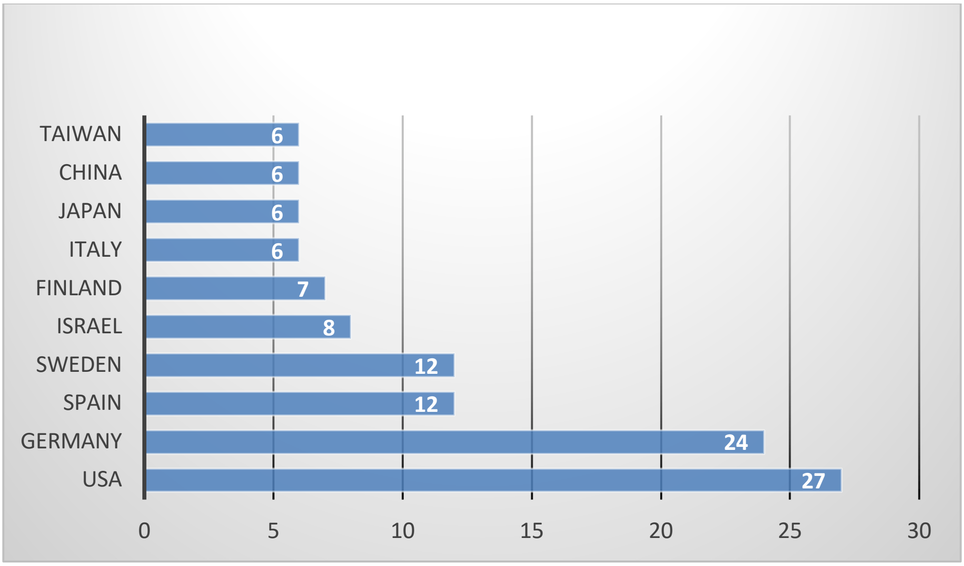
In table 1, it is the top five journals publishing the highest number of articles on sustainability in science education. *Sustainability* ranks first with 31 publications and a 2024 Impact Factor of 3.3, indicating both its prominence and high productivity in the literature. The *Journal of Chemical Education* follows with 10 publications (Impact Factor: 2.9). It reflects the significant integration of sustainability themes into chemistry education. The *International Journal of Science Education (Impact Factor: 2.3)* and *Chemistry Education Research & Practice (Impact Factor: 3.2.)* each published 7 articles. These journals suggest their established reputations and influence in science education research. Finally, *Education Sciences* ranks fifth with 6 publications (Impact Factor: 2.6), highlighting its role in disseminating science research related to sustainability.

Table 1: Top 5 Leading Journal in Scientific Publications

Ranking	Journal Name	Number	Journal Impact Factor (2024)
1	Sustainability	31	3.3
2	Journal of Chemical Education	10	2.9
3	International Journal of Science Education	7	2.3
4	Chemistry Education Research & Practice	7	3.2
5	Education Sciences	6	2.6

In Figure 3, it is shown the top 10 countries contributing to scientific publications on sustainability in science education. The United States leads with 27 publications and followed by Germany with 24 publications. Spain and Sweden share the third position. Each one has produced 12 publications. Israel (8) and Finland (7) also demonstrate notable contributions. Italy, Japan, China, and Taiwan each have 6 publications, indicating a more modest but still significant presence in the research area.

Figure 3: Top 10 Leading Countries in Scientific Publications



In table 2, it is shown that the most influential authors are defined as those with more than 100 citations in the sustainability and science education research area. Ingo Wilks stands out as the most prolific and highly cited author with five publications accumulating 241 citations. Franz Rauch and Mareike Burmeister each have a single publication but share the second-highest citation count (183 citations), suggesting that their individual works have highly influenced sustainability and science education research. Joanne O'Flaherty and Michelle Liddy also appear prominently. Each one with one publication cited 137 times. They have reflected strong academic reputation despite limited output in this dataset. Werner Riess with three publications and 134 citations demonstrates a balance between productivity and influence. Finally, Susanne Boegeholz with two publications and 100 citations contributes to literature.

Table 2: The Most Influential Authors have more than 100 citations

Authors	Total Number of Publications	Total Number of Citations
Ingo Wilks	5	241
Franz Rauch	1	183
Mareike Burmeister	1	183
Joanne O'Flaherty	1	137
Michelle Liddy	1	137
Werner Riess	3	134
Susanne Boegeholz	2	100

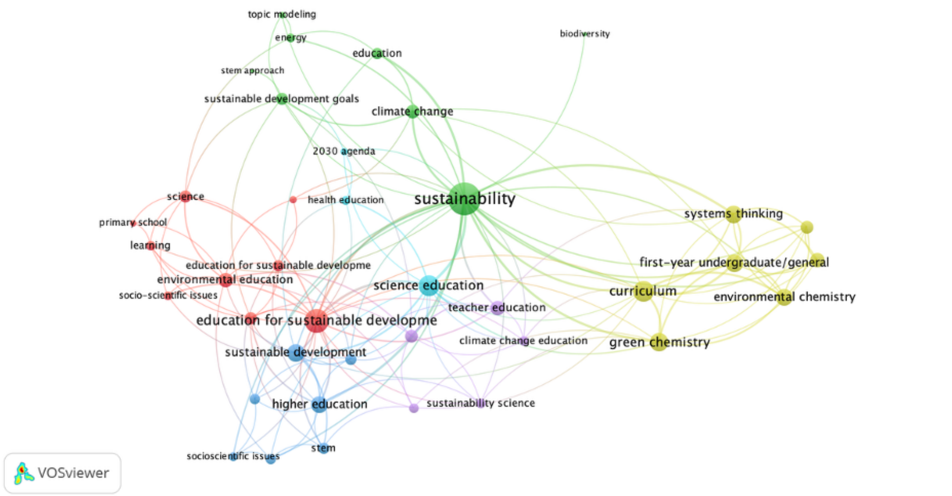
Keyword and thematic analyses

In Figure 4, The keyword co-occurrence analysis reveals the conceptual structure of research on sustainability in science education. The largest and most central node is "sustainability", indicating its role as the dominant and unifying concept across the literature. Similarly, connected keywords are such as "science education", "education for sustainable development", and "green chemistry" which form the core thematic clusters of the field. Co-occurrence analysis focuses on terms relations in publications while theme analysis reveals key words in the abstract of publications. Also, co-occurrence analysis enables revealingly related clusters about key words. The analysis provides a broader perspective and how frequently certain words appear in the abstract and what this reveals about the overall focus of the study.

The analysis also shows several distinct thematic groupings:

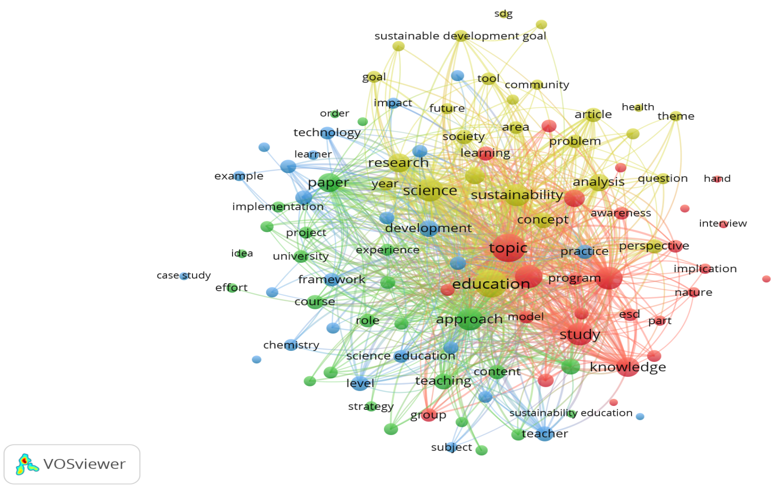
- Yellow Cluster: It includes key words like *system thinking*, *green chemistry*, *environmental chemistry*, and *curriculum*. It focuses on integrating sustainability into chemistry education and curriculum design.
- Green Cluster: It includes key words related to science education like *biodiversity, climate change* and *energy*.
- Blue Cluster: It includes *higher education*, and *sustainable development*. It highlights publications on science education and higher education.
- Red Cluster: It includes *primary school*, *science education*, and *socio-scientific issues*. It reflects studies that address sustainability at the primary and secondary education levels.
- Purple Cluster: It includes *teacher education, climate change education* and *sustainability science*. It indicates publications focused on teacher training and sustainability.

Figure 4: Keyword Co-occurrence Network Analysis



In Figure 5, the theme analysis of abstract terms is based on the most frequently occurring terms in the abstracts of the analyzed publications. It reveals several interconnected clusters and each one represents a distinct thematic focus within the literature on sustainability in science education. The red and yellow clusters contain the most frequently occurring terms in the abstracts. The terms in these clusters are primarily related to concepts of sustainability and are largely associated with science education research. Remarkably, terms such as *sustainability*, *program*, *education*, and *science* emerge as the most prominent within all groups. Although the terms in the green and blue clusters occur less frequently overall. The most common terms are *approach*, *content*, *technology*, and *development*.

Figure 5: Theme Analysis of Abstract Terms



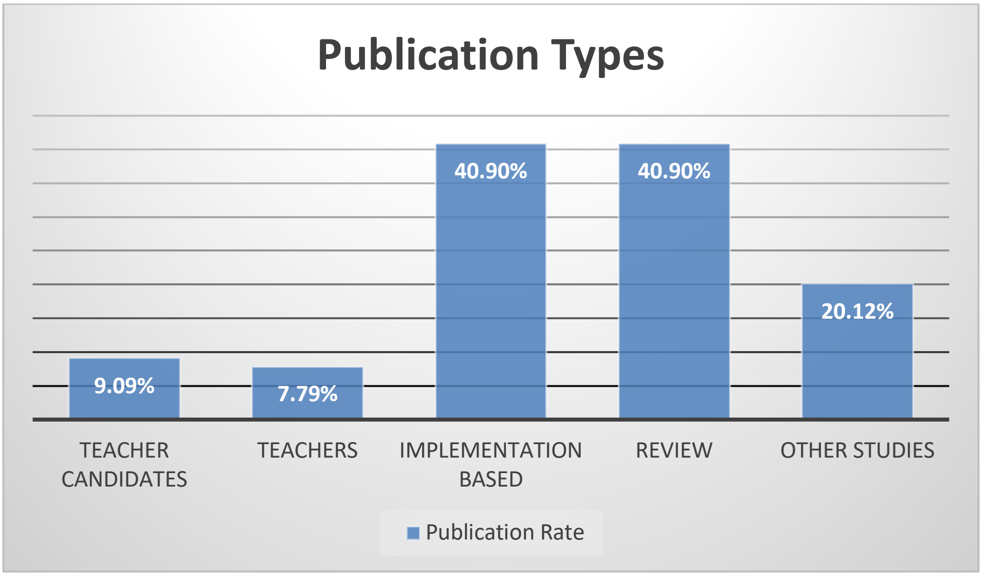
Educational dimensions and research designs

In addition to the trends and descriptive characteristics of the research, it is also important to analyze which dimensions of education these studies focus on and what types of research designs they employ. Therefore, the 154 studies included in the analysis were examined by the researchers to examine their main areas of focus.

In figure 6, it provides the distribution of publication types related to sustainability in science education. In the results, the largest proportion of studies are categorised under two categories: *implementation-based studies* (40.90%) and *review studies* (40.90%). It shows that the field is characterized both by practical applications in educational settings and by comprehensive syntheses of existing research. Within the implementation-based studies, research with a direct focus on technology was found to be rather limited. Instead, these studies were predominantly designed as problem-based research or aimed at fostering sustainability awareness of participants.

On the other hand, studies which represent a smaller proportion focus directly on *teachers* (7.79%) and *teacher candidates* (9.09%). while sustainability is seen as an important theme and its direct investigation in teacher training and professional practice remains relatively limited. Conversely, most of the remaining research aimed at enhancing students' sustainability awareness. Additionally, other types of studies (20.12%) make up a substantial share, and it reflects the diversity of research designs and perspectives employed in this area. In the *other types of studies* category, the focus was on other research designs such as interviews with experts and other participants, situation analysis, and need assessments related to educational programs.

Figure 6: Publication types related to sustainability in science education



Discussion

The findings of this study founded a consistent growth in sustainability research in science education literature. The first appearance of the term starts in 2007 and accelerates markedly after 2018. This situation aligns with global developments in sustainable development goals reported in 2015 and then raising sustainability awareness, which shaped educational curriculum and research worldwide (UNESCO, 2017). Also, comparable upward patterns have been observed in other bibliometric analysis studies on environment and sustainability in education (Dönmez, 2024) confirming the global acceptance integrating sustainability into science education research (Aikens et al., 2018). However, unlike previous studies, the current bibliometric analysis demonstrates how these global trends have been internalized specifically in the science education research literature, including curriculum revisions, inquiry-based teaching, and socio-scientific research-based science education through sustainability concepts. The minor decline in 2025 output probably reflects incomplete data for the year rather than a genuine reduction in the number of the empirical research.

Journal-level analysis highlights the multidisciplinary nature of sustainability in science education, with the journal called *Sustainability* emerging as the most prolific journal. This aligns with the journal's broad scope and open-access model, which have facilitated the divergence of different perspectives on ESD (Zidny et al., 2020). Accordingly, the presence of chemistry education focused journals such as *Journal of Chemical Education* and *Chemistry Education Research & Practice* among the top publishers reflects the established role of chemistry education in sustainability concepts, particularly through green chemistry, water literacy, global warming and climate change which are part of the chemical education process (Burmeister et al., 2012). Also, the *International Journal of Science Education* and *Education Sciences* journals provide evidence that the concepts' engagement with sustainability concepts is both disciplinary and interdisciplinary, consistent with science education research (Alsop & Bencze, 2014).

Country-level contributions demonstrated that the USA and Germany are the leading countries for sustainability in science education research. This finding is consistent with an earlier review article in sustainability in teacher education research conducted by Stevenson et al. (2017) which stated that Germany is the leading country in sustainability research. Also, Germany's predominance is likely linked to Germany's strong sustainability and ESD research policy and frameworks (Grund & Brock, 2020). The high presence of other European countries such as Spain, Sweden and Finland also demonstrates the European Union's deep focus on ESD and sustainability awareness (UNESCO, 2017). Last but not least, the presence of different countries all over the World reflects a broader international commitment to integrating sustainability in science education research (Boeve-de Pauw et al., 2015).

The author-level analysis reinforces the impact of key scholars in sustainability in science education research literature. For example, Ingo Wilks stands out for integrating sustainability with socio-scientific issues, inquiry-based science learning, teacher education, and curriculum design studies. Similarly, Franz Rauch and Mareike Burmeister contribute to bridging theory and practice by emphasizing reflective teaching and sustainability awareness in schools and their curriculum. These findings demonstrate that the influence in the field is not only for school or curriculum but also for out of school learning environments in real and daily life (Feinstein & Kirchgasler, 2015). Therefore, both theoretical and practical contribution to literature develops sustainability awareness in science education research literature. This may lead to a rethink of the purpose and process of contemporary science education research for the future.

The analysis of the keyword co-occurrence in this research indicated a strong conceptual clustering around climate change, biodiversity, citizen science and the SDGs. The importance of climate change, biodiversity loss and SDGs also highlighted in the previous review studies (Aikens et al., 2018; Hallinger & Nguyen, 2020; Li & Wilks, 2021). However, the limitations of previous bibliometric studies specifically focused on sustainability in science education showed the novelty and significance of this present study. For this reason, previous studies suggested exploring underrepresented topics, enhancing cross-national collaborations, and bridge the gap between theoretical frameworks and classroom practice for future review or bibliometric studies. (Zidny et al., 2020). For this reason, this study helps science education literature by mapping conceptual structures, identifying leading and prolific influential authors, and visualizing thematic structures are the strengths of this study.

The theme analysis of abstract terms (Figure 5) highlights the conceptual understanding and meanings of sustainability research in science education literature. The high clustering of frequency terms such as *sustainability*, *education*, *science*, and *program* within the red and yellow groups reflects the centrality of these concepts in science education literature. These clusters demonstrated that most of the literature is anchored in broad discussions about how sustainability is positioned as a research topic and an educational practice (Boeve-de Pauw et al., 2015). On the other hand, the green and blue clusters, while less dominant in frequency. This situation demonstrated that terms such as approach, *content*, *development*, and *technology*, indicating a methodological and implementation-oriented strand within the science research. In short, these clusters illustrated that sustainability in science education research is conceptualized not only as a thematic area but also as a practical educational approach for contemporary science education research literature (Sterling et al., 2020; Wang et al., 2024). The network density and links between these terms illustrate that future scholarship is likely to continue evolving toward greater interdisciplinarity between science and chemistry education. Also, methodological diversity reinforces sustainability as an interdisciplinary d and contemporary area of science education research (Ellegaard & Wallin, 2015).

Last but not least, the analysis of publication types revealed that sustainability in science education is predominantly investigated through both empirical and review studies. Empirical studies revealed classroom-based interventions to improve sustainability awareness (García-Vinuesa, 2024; Zoller, 2012) whereas review or bibliometric studies analyzed the synthesis of existing knowledge (Aikens et al., 2018; Stevenson et al., 2017).

This balance between practice and classroom-based interventions suggests that the sustainability concept is generally seeking to test innovative pedagogical approaches for science teaching and learning. In addition, digital and technological innovations have increasingly been used in science education, however, technology-based interventions remain limited within empirical studies according to the findings of this study. This indicates a potential gap where sustainability-oriented science education could further benefit from the integration of digital tools such as animations, simulations, augmented or virtual reality tools.

The relatively small proportion of studies focusing directly on teachers and teacher candidates (9.09%) is considering the widely recognized role of educators in teaching sustainability to students. Previous research has reported that teachers' beliefs, professional competencies, and pedagogical practices strongly influence how sustainability-related concepts are introduced and implemented in classrooms (Linkwitz & Wilks, 2022). The underrepresentation of in-service and pre-service teachers and focused research in this bibliometric mapping suggests that more attention must be focused not only on pre-service but also in-service teacher education to ensure sustainability becomes embedded in science education research literature (Hallinger & Nguyen, 2020).

Conclusion

This bibliometric analysis study provides a synthesis of sustainability related research in science education literature. This study offered insights into its presence, thematic analysis, and methodological focuses. Empirical and review studies in sustainability in science education research have grown since 2007, with a sharp increase by 2018. United Nations' SDGs are the main reason for this sharp increase. Also, the most active journal in this field is *Sustainability*, even though this journal is not primarily focused on education but sustainability. In addition, chemistry education focused journals addressed green chemistry and socio-scientific issues, showing sustainability interdisciplinary concepts. Leading contributions come from the United States, Germany, and other European countries, reflecting strong policy frameworks for ESD. Influential researchers such as Ingo Wilks, Franz Rauch, and Mareike Burmeister have shaped the field through both theoretical and practical contributions to the literature. Thematic analyses highlight climate change, biodiversity, and the SDGs as central concepts. On the other hand, technology-focused research remains limited according to the findings of this study. Moreover, the limited focus on in- service and pre-service suggests the need for more attention to teachers' roles in improving sustainability awareness. All in all, this study demonstrates that sustainability in science education is a dynamic and rapidly evolving area of science education research h. By identifying trends, gaps, and influential contributions, this study provides a foundation for future research aimed at strengthening teacher education, expanding technology-based interventions, and fostering international collaboration to improve sustainability in science education.

Limitations

Firstly, this present study is focused only on the WoS database. While WoS has most of the comprehensive studies in education and educational research, excluding other databases such as Scopus or ERIC may have led to the miss many other relevant publications. Therefore, in future research, it will be important to include other databases that might improve methodology and strength of the articles. Secondly, the dataset for 2025 was incomplete at the time of analysis. Therefore, the slight decline in publication numbers observed for that year is more likely a methodological limitation than an actual decrease in research area.

Statement on the Use of AI Tools | *On the paper, the ChatGPT 5.0 were used to improve readability and language. In analysis and construct of the paper, any AI tools were not used.*

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