



Bridging ESD Competencies in Environmental Chemistry Learning: A Decadal Bibliometric Analysis

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Abstract. Integrating ESD competencies into the curriculum of environmental chemistry courses is essential to foster a generation capable of addressing intricate environmental issues. This research aims to know the development of Education for Sustainable Development (ESD) competencies in Environmental Chemistry Learning in scientific articles in Scopus. The methodology used in this study is bibliometric, with an analysis of the development in the scientific literature and co-words. The articles have been studied using the Scopus database for the last ten years (2013-2023). Scopus and VOSviewer were used to extract the results, and 162 journal articles and conference papers were analyzed. We limit the search in the Scopus database to only the subject areas of social sciences, environmental science, and chemistry and document types of article journals and conference papers. The bibliometric analysis reveals several interesting findings. First, there is a growing interest in ESD competencies in Environmental Chemistry Learning, as indicated by the increasing number of publications over the last ten years. Second, the identified main research themes include innovative approaches to train ESD competencies in Environmental Chemistry Learning, which still have significant potential for further development. This is depicted in the network, density, and overlay visualizations based on co-citation networks. Third, this study references the relationship between ESD competencies and environmental chemistry Learning. Finally, a discussion and conclusion of the results have been carried out, which can serve as a turning point for future lines of research on developing an environmental chemistry course program to improve ESD competencies. The prospect of this research is significant in shaping the future landscape of education and environmental science. By integrating Education for Sustainable Development (ESD) competencies into the curriculum of environmental chemistry courses, the aim is to develop a generation with the knowledge and skills necessary to address complex environmental challenges. This research recognizes the importance of instilling ESD competencies and endeavors to understand and analyze this integration's current state and trends.

Keywords: Bibliometric Analysis; Chemistry education; Environmental Chemistry; ESD Competences.

1 Introduction

Focusing on sustainability is becoming increasingly important in the ever-evolving world of education [1-3]. Recognizing the importance of addressing environmental challenges, Education for Sustainable Development (ESD) has emerged as an essential approach to instilling competencies that prepare students for a world shaped by environmental concerns. Integrating ESD in education includes transferring knowledge and forming attitudes and values that create individuals who care about the environment [4-6]. By incorporating these aspects into the curriculum, education can drive change towards a sustainable society [7].

As technology and information develop, environmental challenges become more complex, and a deep understanding of the relationship between environmental science and sustainability becomes more urgent [8-11]. Therefore, ESD is about teaching scientific facts and developing analytical and critical skills to deal with complex issues involving human and environmental interactions. Facing climate change and environmental degradation, the role of ESD in forming a generation that has the competence and skills to contribute to sustainable solutions is increasingly deepening [12-13]. In this context, analysis of research trends related to ESD competencies in environmental chemistry learning becomes increasingly relevant to ensure effective and responsive education to future needs.

As a branch of science, environmental chemistry plays a vital role in understanding the complex relationships between chemical processes and the environment [14-15]. The synthesis of ESD competencies with environmental chemistry learning is essential to fostering a generation of learners equipped with the knowledge and skills to address pressing environmental problems. This analysis seeks to provide insight into how educators and researchers navigate the integration of ESD in the context of environmental chemistry education. Therefore, it is essential to recognize the importance of global sustainable development and the critical role of education in achieving it. Environmental challenges such as climate change, pollution, and resource depletion require a transformative educational approach by applying learning approaches that empower students with awareness, knowledge, and the ability to contribute to sustainable solutions [16-21]. The analysis presented here aims to contribute to the ongoing discourse regarding effective strategies for incorporating ESD competencies into curricula, with a particular focus on the dynamic field of environmental chemistry.

It is essential to understand the current state of research, identify emerging trends, and examine the implications for educators, policymakers, and researchers involved in integrating ESD competencies into the structure of environmental chemistry education. By doing this, we aspire to foster a deeper understanding of the challenges and opportunities in cultivating environmentally conscious and competent citizens through education. This article explores research trends related to ESD competencies, especially in the environmental chemistry learning domain. By reviewing recent studies and scientific discourse, we seek to provide an account of key developments, challenges, and potential solutions in integrating ESD into the teaching and learning of environmental chemistry.

This research will provide a substantial contribution to the analysis regarding the integration of Education for Sustainable Development (ESD) competencies into the curriculum, especially in the dynamic domain of environmental chemistry. By emphasizing the increasing significance of sustainability in education and recognizing the emerging challenges related to environmental issues, this study emphasizes the critical need to embed ESD into the educational framework. This research aims to review the current research landscape, identify emerging trends, and explain the implications for educators, policymakers, and researchers involved in inserting ESD competencies into environmental chemistry education. Through this analysis, the researchers aim to deepen understanding of the challenges and opportunities inherent in cultivating environmentally aware and competent citizens through education.

By delving into the intersection between ESD and environmental chemistry, this article seeks to provide valuable insights, addressing the imperative of transformative educational approaches amidst climate change, pollution, and resource depletion. A thorough examination of research trends not only aims to provide a detailed account of key developments but also provides insight into the challenges educators and researchers may face during the integration process. Ultimately, this research intends to establish an effective strategy for integrating ESD competencies into environmental chemistry curricula, provide a foundation for future research, and propose potential solutions to improve environmental chemistry teaching and learning in the context of sustainable development.

2 Methodology

The data used in this research was obtained from research published in journals and conference papers indexed in Scopus. Scopus was chosen as a data source because it covers various scientific disciplines such as social sciences, natural sciences, health sciences, and humanities [22]. Scopus is considered a quality data source because it applies strict assessment methods to determine the journals' quality in its database [23]. Besides that, Scopus also provides information regarding the impact factors of the journals recorded in the database [24]. Impact factor is one of the leading indicators used to evaluate how often articles in a journal are cited by other researchers, which helps researchers assess the extent to which a journal influences a particular field of study. The existence of Scopus is widely recognized in the international scientific community [25-27].

Literature research on the selected topic has been conducted using a reference management application called Publish or Perish. Previous research provided detailed information regarding how to use and install this application and the steps that need to be followed to collect data. In addition, the methodology for searching data from Scopus through libraries [29-30].

This research was carried out through a series of stages, as illustrated in Fig. 1. The following steps were involved: (1) Collection or collection of publication data using the publish or perish application; (2) Processing bibliometric data for articles obtained us-

ing the Microsoft Excel application; (3) Computational Mapping or carrying out computational mapping analysis of bibliometric publication data using the VOSviewer application, and (4) Analyzing the results of computational mapping analysis. Searching for publication data using the Publish or Perish application aims to filter publications by applying the keyword "Education for Sustainable Development (ESD) Competences in Environmental Chemistry Learning" and meeting the title requirements. The selected papers were published between 2013 and 2023, and data collection was completed in August 2023. After collecting relevant articles, the results were exported in two file formats: research information systems (.ris) and comma-separated value format (*.csv). Article data obtained from the source database was mapped using VOSviewer, which produces three types of publication maps: network visualization, density visualization, and overlay visualization based on co-citation networks between the articles. A minimum keyword frequency threshold is created three times to create a bibliometric map, and less relevant keywords are removed.

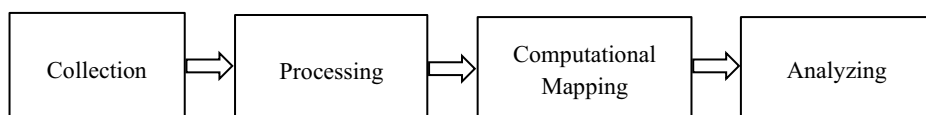


Fig. 1. Bibliometric Mapping Procedure

Collecting publication data using the Publish or Perish application is a valuable tool for researchers and academicians. This application enables the systematic gathering of information related to scholarly publications, offering insights into citation metrics, authorship patterns, and academic impact. Researchers can efficiently compile and analyze their publication records, track citation counts, and assess their academic influence by utilizing the Publish or Perish application. This process aids in evaluating the impact of individual publications and provides a comprehensive overview of a researcher's scholarly contributions, facilitating informed decision-making regarding research strategies and career development.

Processing bibliometric data for articles using the Microsoft Excel application is a fundamental and efficient method in academic research. Excel provides researchers with a user-friendly platform to organize, analyze, and visualize bibliometric information, allowing for the extraction of valuable insights. Researchers can employ Excel's diverse functions to calculate citation metrics, identify publication trends, and create graphical representations of data patterns. Additionally, the software's spreadsheet capabilities enable the systematic arrangement of bibliographic details, facilitating a comprehensive overview of research outputs. Utilizing Microsoft Excel for bibliometric analysis streamlines the data processing workflow and empowers researchers to derive meaningful interpretations and draw informed conclusions from their scholarly endeavors.

Conducting computational mapping analysis of bibliometric publication data through the VOSviewer application is a sophisticated approach that offers in-depth insights into the scholarly landscape. VOSviewer enables researchers to visually represent and explore complex relationships among publications, authors, and keywords.

The application uses advanced algorithms to create maps highlighting related research clusters, helping researchers identify critical themes, influential authors, and emerging trends within a specific field. The interactive features of VOSviewer facilitate dynamic exploration and customization of maps, allowing researchers to delve into the network structure of their bibliometric data. This computational mapping process enhances the comprehensibility of complex bibliometric information and serves as a valuable tool for researchers seeking a nuanced understanding of the intellectual structure and knowledge domains within their field of study.

Analyzing the results of computational mapping analysis is a crucial step in extracting meaningful insights from bibliometric publication data. Once the data has been processed through applications like VOSviewer, researchers must interpret the visualized maps and identify patterns, connections, and clusters within the scholarly landscape. This analysis examines the proximity of nodes, the frequency of keyword co-occurrence, and the strength of connections between different research themes. Researchers can uncover the intellectual structure of the field, identify influential nodes or authors, and discern emerging trends. Additionally, scrutinizing the overlay visualizations and density maps provides a nuanced understanding of the relationships between various topics. This analytical phase is instrumental in concluding, recognizing research gaps, and formulating future directions for scholarship in the examined domain. Overall, analyzing computational mapping results adds depth to the bibliometric study, offering valuable insights that contribute to the broader understanding of the research landscape.

3 Result and Discussion

A comprehensive search was conducted in the Scopus academic database to obtain articles related to environmental chemistry lectures and Education for Sustainable Development (ESD) competencies in the last ten years. Based on bibliometric studies with Scopus, data sources are limited to document types in articles and conference papers. The data search was divided into three keyword scopes: environmental chemistry lectures with conservation insight, environmentally friendly packaging technology, and Education for Sustainable Development (ESD) competencies. Then, the data was processed using the VOSviewer application, and the analysis focused on co-citation analysis, co-occurrence analysis, and keywords to identify primary research themes and influential publications. The data obtained in this literature study consisted of research published in journals totaling 155 articles and conference papers totaling seven articles from the Scopus database.

Bibliometric mapping analysis revealed several interesting findings. First, there is increasing interest in environmental chemistry lecture themes and Education for Sustainable Development (ESD) competencies, as shown by the increasing number of publications in the last ten years. The graph in Fig. 2 shows that the trend of publications on the topic under study is increasing, except in 2015, 2016, and 2022.

distinct research areas on the foundations of science education for sustainable development. First, "Education for Sustainable Development" is part of cluster 1, characterized by 177 total links, 687 total link strengths, and 145 occurrences. Second, "environmentally friendly packaging technology" relates to cluster 3, with 66 links, 133 total link strengths, and 30 occurrences. Finally, "sustainable development" falls into cluster 6, showing 25 links, 52 total link strengths, and 17 occurrences.

The intricate network of research topics within conservation-oriented environmental chemistry lecture programs, environmentally friendly packaging technology, and ESD competencies are vividly presented in Fig. 4. This overlapping visualization highlights the interconnectedness of these themes and underscores the burgeoning interest in these areas. Accentuates the contemporary relevance and ongoing exploration within related terms. Over an extended period, the terms conservation-oriented environmental chemistry, environmentally friendly packaging technology, and ESD competencies have grown in popularity, reflecting a sustained enthusiasm for investigating these subjects.

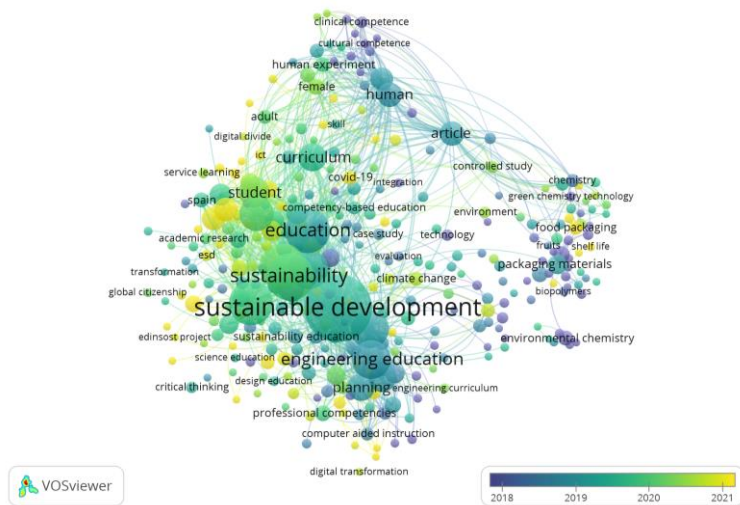


Fig. 4. Overlay Visualization According to Research Area (2013-2023)

Fig. 4 displays an overlapping visualization of research topics regarding conservation-oriented environmental chemistry lecture programs, environmentally friendly packaging technology, and Education for Sustainable Development (ESD) competencies. This visualization shows the novelty of research regarding related terms [31-32]. The terms conservation-oriented environmental chemistry, environmentally friendly packaging technology, and Education for Sustainable Development (ESD) competencies have become popular over a long period in research, indicating the ease of conducting new research in this field.

environmental problems stem from a need for more education about the environment and ways to lead a sustainable life. In connection with this problem, UNESCO has an approach to learning known as ESD (Education for Sustainable Development), which it feels can provide a solution.

Several noteworthy findings have emerged based on the results of the comprehensive bibliometric analysis conducted using Scopus data over the past ten years. The increasing interest in environmental chemistry lectures and Education for Sustainable Development (ESD) competencies is evident from the rising number of publications, except for minor fluctuations in 2015, 2016, and 2022 (Fig. 2). The primary research themes identified encompass environmental chemistry lectures, conservation insight, environmentally friendly packaging technology, and ESD competencies, as depicted in the network, overlay, and density visualizations (Fig.s 3, 4, and 5).

The network visualization illustrates three distinct clusters, emphasizing the interconnectedness of "Education for Sustainable Development," "environmentally friendly packaging technology," and "sustainable development" within the broader context of conservation-oriented environmental chemistry lecture programs (Fig. 3). The overlay visualization further underscores the popularity and sustained interest in these research areas over time, highlighting the ease of conducting new research in this field (Fig. 4). The density visualization adds another layer of understanding by emphasizing the prevalence of critical terms, such as "sustainable development," "engineering education," "education," "environmental chemistry," "packaging materials," "curriculum," "human," and "climate change" (Fig. 5).

Based on these results, the analysis delves into the significance of ESD, elucidating its support for five fundamental types of learning to cultivate sustainable individuals. ESD is a learning process crucial for various levels and types of education, with a primary focus on preparing the younger generation to become responsible citizens and contributors to sustainable development. The study also highlights UNESCO's perspective on ESD as a transformative approach to addressing environmental challenges by instilling values, knowledge, and habits conducive to sustainability. In summary, the research findings provide a comprehensive overview of the current landscape of environmental chemistry education and ESD competencies, paving the way for informed discussions and future directions in this vital intersection of education and sustainability.

While this study provides significant insights into the trends and dynamics of environmental chemistry education and Education for Sustainable Development (ESD) competencies, it grapples with certain limitations. The exclusive reliance on data from the Scopus academic database raises concerns about potential bias, as it hinges on the journals and conferences indexed in Scopus. The study's focus on document types like articles and conference papers further narrows the scope of analysis, potentially excluding relevant information from other sources. Moreover, the chosen keyword scope for the data search, concentrating on environmental chemistry lectures with conservation insight, environmentally friendly packaging technology, and ESD competencies, might inadvertently overlook emerging themes or alternative terminologies used by researchers, leading to a partial representation of the broader landscape in environmental edu-

cation and sustainability. While providing a comprehensive overview, the use of bibliometric mapping analysis might struggle to capture the depth and nuance of qualitative aspects, as the vividly presented visualizations may not fully encapsulate the complexities and interrelationships within these thematic areas.

The observed fluctuations in publication trends during specific years, such as 2015, 2016, and 2022, could be attributed to external factors like global events or changes in research focus, necessitating a more in-depth qualitative analysis beyond what the bibliometric approach alone can provide. Furthermore, relying solely on bibliometric data from the Scopus database may underrepresent contributions from other databases, potentially limiting the comprehensiveness of the findings. In conclusion, while offering valuable quantitative insights, this research underscores the importance of acknowledging these limitations and advocates for future research to incorporate a more diverse array of data sources, explore alternative keyword scopes, and integrate qualitative approaches for a holistic understanding of the integration of ESD competencies into environmental chemistry education.

4 Conclusion

In conclusion, this research significantly contributes to the ongoing discourse surrounding the integration of Education for Sustainable Development (ESD) competencies into the curriculum, particularly within the dynamic domain of environmental chemistry. The analysis sheds light on key developments, challenges, and potential solutions, providing valuable insights for educators, policymakers, and researchers engaged in this critical intersection of education and sustainability. The study reveals a growing interest in environmental chemistry lectures and ESD competencies, with a notable rise in publications over the past decade, underscoring the urgency and relevance of this field. The identified research themes, including environmental chemistry lectures, conservation insight, environmentally friendly packaging technology, and ESD competencies, reflect the multifaceted nature of the discourse. The network, overlay, and density visualizations highlight the interconnectedness of these themes, emphasizing their sustained popularity and the ease of conducting new research in these areas.

An in-depth exploration of ESD underscores its pivotal role in fostering sustainable individuals through five fundamental types of learning: learning to know, learning to be, learning to live together, learning to do, and learning to transform oneself and society. UNESCO's perspective on ESD as a transformative approach aligns with the broader goal of addressing environmental challenges by instilling values, knowledge, and habits conducive to sustainability. However, the study acknowledges limitations, such as potential bias from exclusive reliance on the Scopus database and the narrow focus on specific document types. The observed fluctuations in publication trends during specific years raise the need for further qualitative analysis beyond bibliometric approaches. Additionally, the study encourages future research to incorporate diverse data sources, explore alternative keyword scopes, and integrate qualitative methodologies for a more comprehensive understanding of the integration of ESD competencies

into environmental chemistry education. This research provides a foundation for informed discussions, policy considerations, and future directions in the vital intersection of education, environmental chemistry, and sustainability. By addressing the challenges and opportunities outlined in this study, educators and policymakers can advance effective strategies to embed ESD competencies into the educational framework, ultimately contributing to cultivating environmentally aware and competent citizens prepared to address pressing global challenges.

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