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Implementation of Biotechnology in Education towards Green Chemistry Teaching: A Bibliometrics Study and Research Trends

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Abstract

Over the ten years, there has been consistent research effort in chemistry education. However, just a few diverse points of view were documented in terms of research bodies. Thus, the purpose of this study was to use bibliometric analysis to assess the trend bodies of research on biotechnology in education towards green chemistry during the last decade (2012-2022). Data was gathered from scopus-indexed documents using the 'title' search results. For additional examination, 420 finished documents from various study categories were employed. The bibliometric review was completed using conventional bibliometric indicators utilizing two software programs (Harzing Perish and VOSviewer). This investigation discovered 3 different categories of papers produced that are linked to biotehnology, education, and green chemistry teaching. Articles account for 42% of all publications. Journals are the most common sort of source (91%). Then there was an increase in the number of relevant publications. Based on a bibliometrics analysis of future research trends, four study concept potentials were constructed; and as a result, it was possible to assume that, even though many studies of green chemistry teaching are found, some insights can still be approached in such a way that the practical implementation of biotechnology in learning systems is better used.

Keywords: *Biotechnology, green chemistry, teaching, bibliometrics, research trends.*

1. Introduction

Applied biotechnology in education can represent a source of topics for green chemical teaching. The development of biotechnology and green chemistry issues based on research findings might result in the formation of development initiatives that include both giant education systems and developing nations such as Indonesia [1]. Indonesia is considered one of the world's most biodiverse countries, and its future education is dependent on the careful utilization of its natural resources [2]. Indonesia, as a developing country, has proclaimed a policy to increase environmental awareness on issues such as biotechnology while guaranteeing resource sustainability [3]. The goal of biotechnology in education is to boost the country's competitiveness and educational growth [4]. In the future, green chemistry and biotechnology initiatives can encourage innovation in environmentally friendly technologies [5]. With the approval of the 2030 Agenda for Sustainable Development and other recent government efforts, there is indeed a strong push to bring green chemistry teaching using biotechnology to the forefront of educational implications [6]. The primary goal of green chemistry teaching is to cultivate and increase scientific literacy in sustainable development as well as to develop the necessary abilities in upcoming generations [6, 7]. One of the most effective options for establishing education targeted at the establishment of green chemistry is to enlist young engineering students in biotechnology who will demonstrate a growing interest in generating practical answers to the world's sustainability concerns [8].

In 2018, Blamey et al. found to expand green chemistry applications in the class, students must address social aspects that go beyond the principles of green chemistry. This has the extra advantage of increasing academic achievement with the biotechnology topic [9]. According to Dicks, Biotechnology transformations are typically under-documented in terms of a green chemist's requirement to assess reaction performance [10]. Other authors have reinforced the requirement of green chemistry and green chemistry teaching in biotechnology, as well as the mention of teaching techniques [11–13]. The study aims to get an empirically informed perspective on the development of green chemistry education research on biotechnology during the last decade using bibliometric analysis. The bibliometric, according to Mora, is a collection of tools for statistically analyzing published research and technology [14]. Previous studies, which included three bibliometric articles, identified in the academic papers of literature that dealt with green chemistry in some way, were designed to explain the absence of publications with bibliometric features connected to the green chemistry teaching keyword. It includes the author's name, and the journal in which it was posted, including the title and purpose of the piece. Although bibliometric studies in green chemistry and all of its subfields have previously been published, the vast trend concept of future studies connected to the biotechnology issues was not discovered in the scholarly literature. This is a significant distinction from the current article. This article provides a complete overview of the green chemistry teaching on biotechnology in education, starting with a study of over 420 published publications and narrowing this group down to more influential papers and researchers.

2. Materials and methods

2.1 Theoretical and technical methods of biotechnology and green chemistry

Green chemistry attempts to produce safer and more ecologically friendly chemical reactions and procedures [15]. It takes into account issues such as waste avoidance, energy consumption, safe and non-hazardous chemical reaction, renewable resources, and contamination [16]. Green chemistry principles, on the other hand, should apply not only to chemical changes but also to chemical products, but also to processes utilized in biotechnological processes and the product lines that come from them [17]. Technologies established and researched to make chemical reactions more environmentally friendly can also help to "green" biotechnological operations [18, 19]. Biotechnology is a branch of technology that makes use of biological systems, live creatures, or components of them to develop or produce various goods [20]. Biotechnology has garnered the greatest attention among the various new technologies that have emerged

since the 1970s [21, 22]. Biotechnology has shown to be capable of creating vast riches and impacting every major area of education [23–25]. Biotechnology has already had a significant impact on healthcare, food production and processing, agriculture and forestry, environmental protection, and the manufacturing of minerals and chemicals [23]. One of the numerous definitions of biotechnology is the manufacture of cells or portions of cells [26]. From the type of biotechnology reaction, there is a categorization system for enzymes that defines the many enzyme reaction possibilities [27] (see Figures 1, 2, and 3).

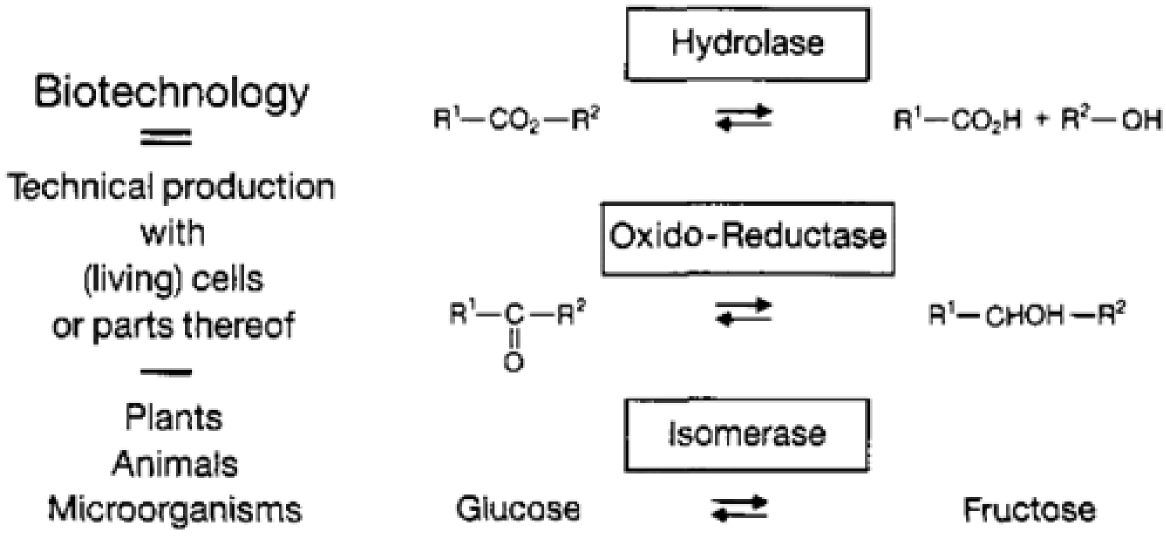

Figure 1. Biotechnology reaction

Biological reactions exhibit a high degree of stereospecificity in many circumstances (Figure 2). This has an effect on chemical intermediates as a starting material for further synthesis. A bioprocess begins with a substrate, then adds a catalyst-in this example, a biocatalyst-and ends up with a product. It's similar to chemistry in many ways.The core of Green Chemistry is the effective use of (ideally renewable) natural resources, including energy resources, waste elimination, and the use of harmful and/or hazardous solvents, in chemical processing and application.

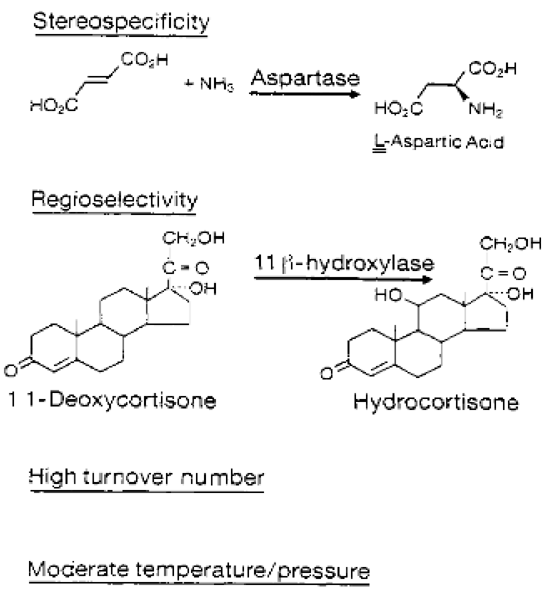

Figure 2. Bioprocess in chemistry

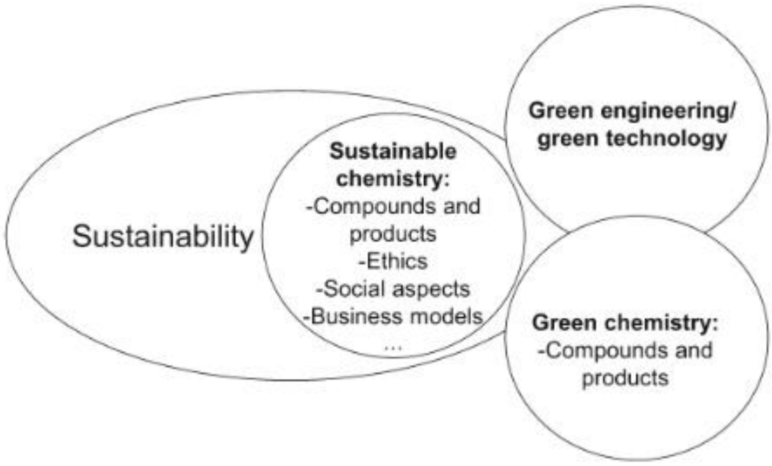

Figure 3. Green chemistry, green engineering, green technology, sustainable chemistry, and their relation to sustainability

The relationship between biotechnology and chemistry may be seen from a variety of perspectives. Examples are given of how green chemistry and biotechnology may be linked to improving the sustainability of substrate supply, upstream and downstream processing, and product production (Figure. 3). These activities, known as bioreaction processes, involve the creation of valuable metabolites or materials, as well as the removal of hazardous chemicals, employing tools and methods from modern biology and engineering.

2.2. Technical Method of Bibliometric Analysis

The initial stage of the bibliometric analysis was to scan the online databases for all available publications relevant to green chemistry to collect a set of data in biotechnology education. The study period included the years 2012 to 2022. To evaluate the data in these papers, the metadata associated with them was imported into Microsoft Excel 2013. Scopus allows us to import files straight from the database, which helps us determine which articles are only dedicated to green chemistry confined to biotechnology in education. The titles and abstracts of all the articles were also imported. Those that did not comply with the requirements of this study were deleted after reviewing the article's text. Collecting data keywords were "biotechnology", "education", "green", chemistry", and "teaching." We combined the search terms using one of these keywords and Boolean operators as follows: Biotechnology education green chemistry teaching: ("biotechnology", "education", "green", "chemistry", and "teaching"). Thus, the first recognized publications distinguish numerous categories, such as journal articles, conference papers, reviews, books, and other publishing forms for additional study. VOSviewer software is used for analysis. This program is used in this research to generate multiple visualization maps based on bibliographic data, such as keyword co-occurrence, co-authorship, citation, and co-citation maps [28-30]. A word is represented by each circle on the VOSviewer visual map. The term activity is indicated by the circle and text size. The huge circle and letters show the chosen terms in a field. The gap between two words denotes the degree of their relationship. In this case, a short distance between two words indicates a more solid link between them. In this article, a systematic mapping study (SMS) technique provided by Fellnhofer (2019) was used. The most trustworthy and exact approach for mapping the research material is bibliometric coupling and direct citation analyses. SMS can also cluster and visualize interconnected contributions and contributor networks. VOSviewer software was also used to create data clusters. The concept of the clusters is determined by analyzing the

titles, abstracts, and keywords of each article inside the cluster. The analytical process in this study is highlighted in Table 1.

Table 1. The Analytical Process of Bibliometric Analysis

No.	Steps	Database	Remarks
1.	Data collection	Scopus database	Timespan: 2012 to 2022 with keywords/terms, title, abstract ("biotechnology" and "education" and "green" and "chemistry" and "teaching"). 1000 documents related to biotechnology have appeared. Type of document: Journal article. 420 articles appeared for further analysis.
2.	Analysis and identification	VOSviewer	420 documents were automatically identified for bibliometric analysis
3.	Further analysis and map	VOSviewer	Descriptive analysis of bibliometric information;
4.	Research topic interpretation	Qualitative interpretation	The authors reviewed the titles, abstracts, and keywords and analyzed each research topic

Our first search found 1000 papers, which were then examined, yielding a total of 420 publications see Figure 4. The average yearly publishing of studies on biotechnology and green chemistry teaching was 37 articles per year, with a 9,09 percent annual fluctuation increase. The overwhelming of papers include original articles (n = 84 percent) and reviews (n = 6,6 percent)(Table 2).

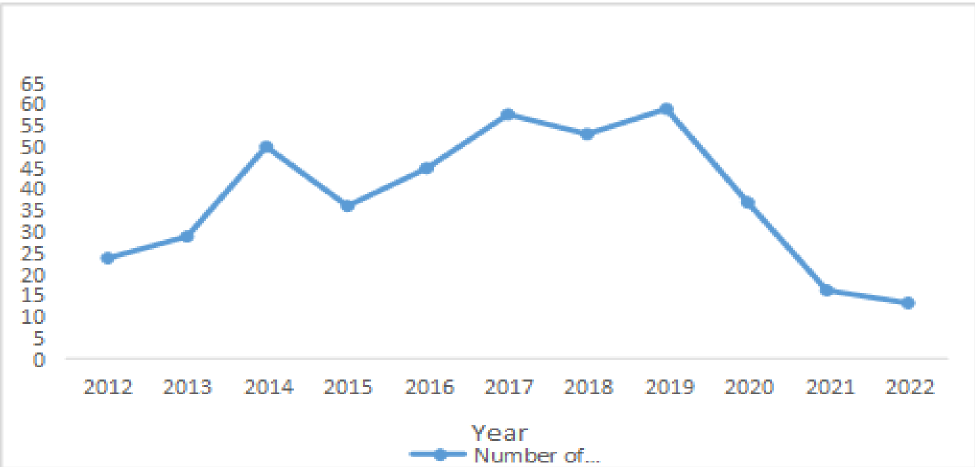

Figure 4. The average yearly publishing of studies on biotechnology and green chemistry teaching

Table 2. Type of document and its percentage

No.	Type of Document	Number of document	Percentage
1.	Book	35	8.3%
2.	Proceeding	4	0.95%
3.	Journal	381	91%
	• original research	353	(84%)
	• review	28	(6.6%)

According to keyword analysis, we gain some fundamental understanding of the basic biotechnology education towards green chemistry teaching, which corresponds to the authors' objectives. Using the Scopus database and VOSviewer program [31], we created a network of title and abstract co-occurrences (Figure 5) based on biotechnology education and green chemistry teaching publications. In this work, the following VOSviewer settings were used to build the co-occurrence map: we employed full counting, a keyword had to appear at least seven times, and the number of clusters was selected based on causal inference. Keywords that were not related to our study were manually eliminated, as were terms that organize abstracts such as "students," "method," and "nano." It was utilized by VOSviewer's text mining tool to identify terms from titles and abstracts [32]. This program generates a co-occurrence network of keywords and presents it on a double map. Two keywords are considered to co-occur if they appear in the same title/abstract, and keywords having a greater incidence of co-occurrence likely to be found closer to each other. A total of 73 keywords that appeared seven or more times were retrieved. As shown in Figure 6, 4 clusters were developed, with cluster 1 addressing biotechnology and teaching, learning, and chemistry, which corresponds to the authors' expectations. Cluster 2 is concerned with the more familiar concept including the chemistry and chemistry teacher. Cluster 3 focuses on synthesis and green method, and Cluster 4 on green chemistry and teacher, which is shown in Figure 5.

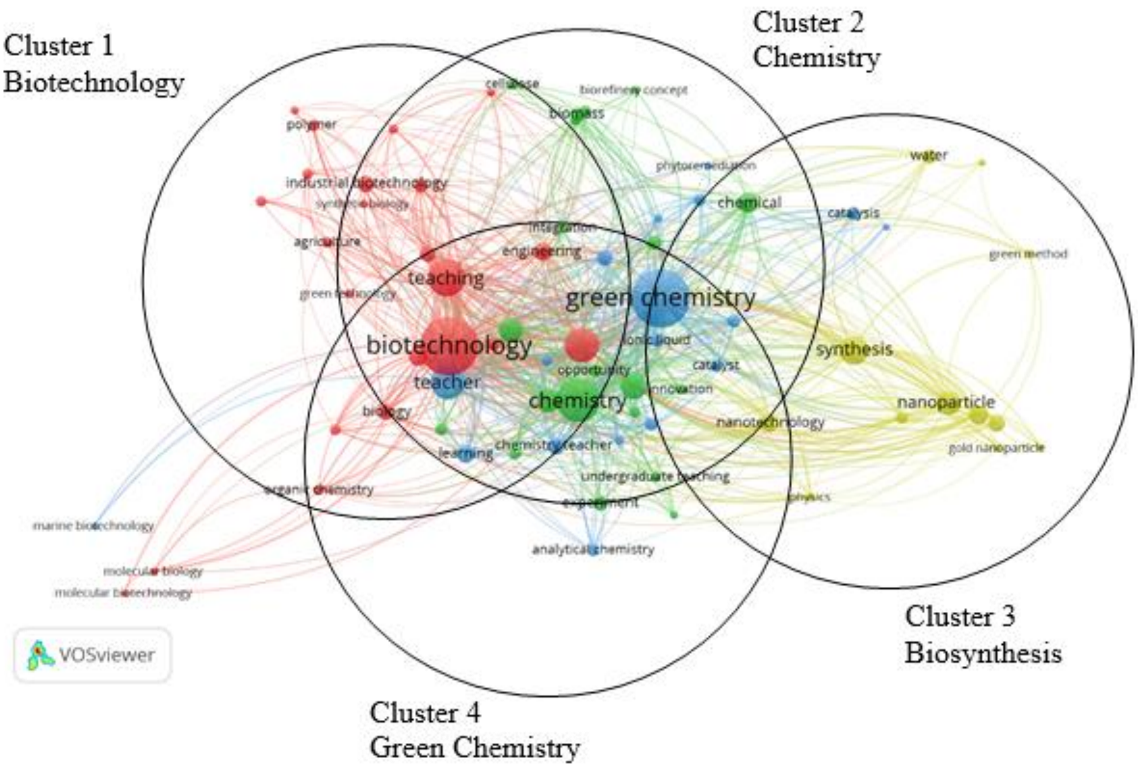

Figure 5. Network visualization of Biotechnology and green chemistry teaching

The network of co-occurrence of keywords clearly showed the main aspects addressed in keyword distribution in biotechnology with learning and teaching concept, which establishes a solid foundation of keyword co-occurrence frequency analysis, according to the analysis of the network, which has 706 nodes and 2675 connections between them. Using Scopus database data and the program VOSviewer, we created an overlay visualization of title and abstract co-occurrences (Figure 6) based on biotechnology and green chemistry teaching. We could see the trend of biotechnology and green chemistry research from 2012 up to 2022 by seeing Figure 6.

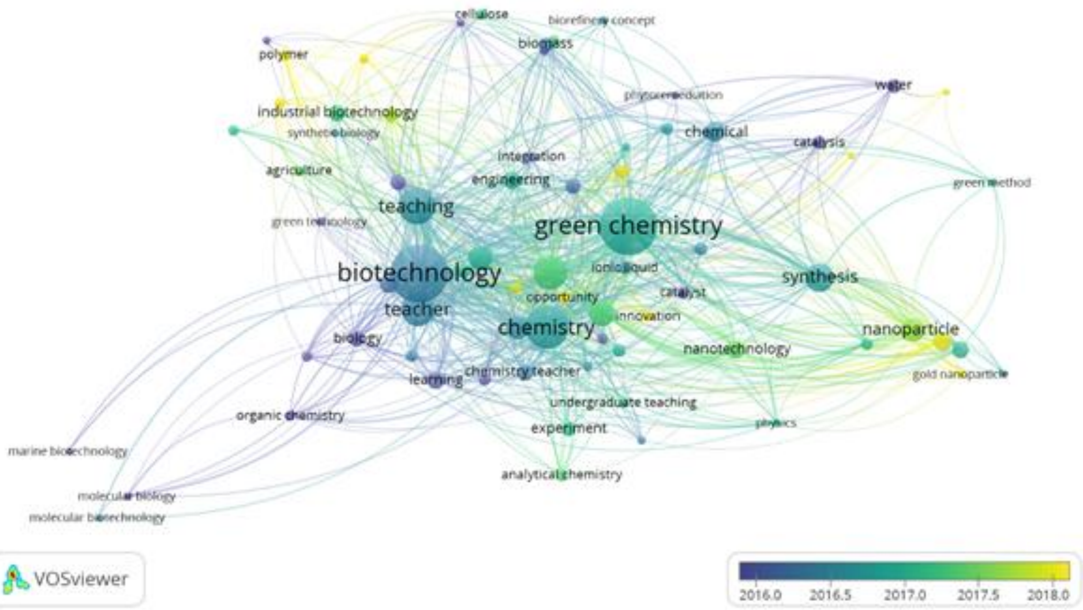

Figure 6. Overlay Visualization of Biotechnology and green chemistry teaching

To more specifically define the relevant topics of the detected trend groups in density visualization, the terms of each article were chosen, and those with a prevalence of two or more in the group's papers were selected (Figure 7). In comparison to all groupings of terms, four keywords stand out: biotechnology; green chemistry; teaching; chemistry.

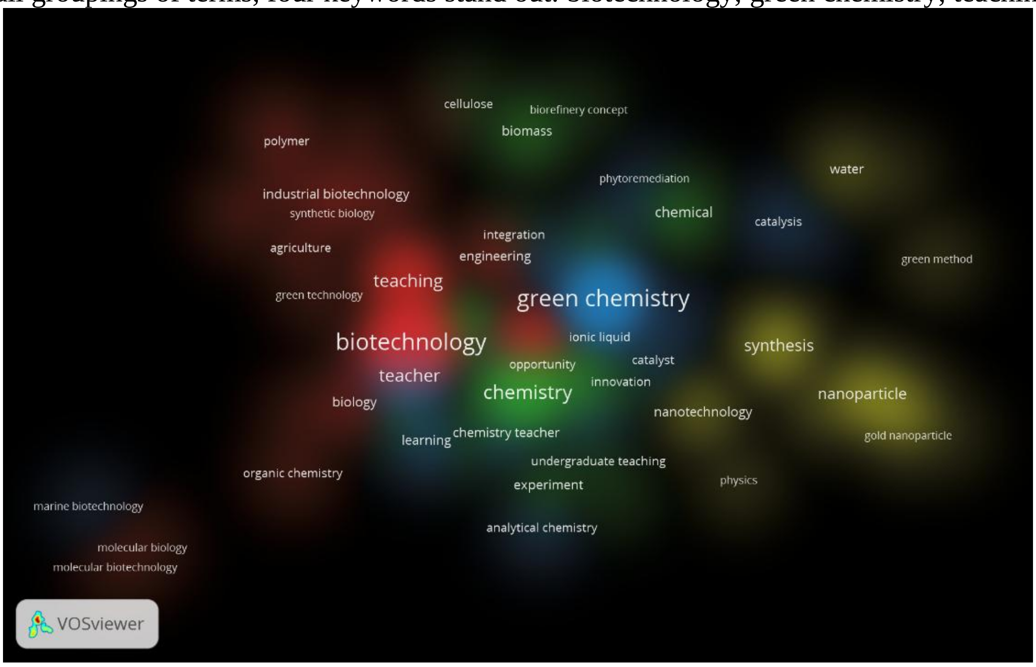

Figure 7. Overlay visualization of biotechnology and green chemistry teaching

As a result, only the 420 remaining articles depicted in Figure 7 were examined. As shown in Figure 7, we split the gaps in the scientific literature of these 420 articles into 4 themes (shown in an as big circle). There is a wide range of difficulties from the observed gaps in future mapped research inclinations. Even though some of the plotted trends pertain to biotechnology, this is not covered as thoroughly as other gaps in the literature. Seetharaman et al. discovered that biotechnology education does not directly affect the use and improvement of green chemistry teaching, but they are co-related to nanotechnology, analytical chemistry, and the green method, influencing teaching and learning

indirectly [33]. 73 keywords were organized and sorted into the four patterns detected in the articles for the analysis. The findings of the keywords suggest that the level of knowledge variety is significant, as seen by the growth in distinct terms. For analysis, we established a network of title and abstract co-occurrences that easily demonstrated the primary topics covered and also gave an approximate picture for future study[31]. In terms of authors and institutions, the VoSviewer program was used to recognize the nations of co-authors and examine their relationships[34]. The co-author network is severely fragmented, and the concentration ratio is low, indicating that just a few writers form strongly grouped flocculation. Four major trends have been identified for future research: (1) Biotechnology; (2) Green chemistry teaching; (3) Green method; (4) Nanotechnology; The four identified trends carry research potentials, which discuss, for instance: perspective for use biotechnology education or industrial for green chemistry [5]. Overall, the preferences of academics who investigate the study point of the piece should indeed be concentrated and linked to the type of biotechnology such as marine biotechnology, molecular biotechnology, and industrial biotechnology inserted in the context of the circular education, as these are the trends that appear most frequently in some studies. Although numerous research on the present topic has been discovered, certain concepts can still be tackled in such a manner that the practical application of biotechnology and green chemistry is spread [25]. This result also confirms the effectiveness of bibliometric analysis [35-51] to explore and visualize the current literature that can be used for deciding whether further research be done. This study may help researchers come up with suggestions for future studies on green chemistry education, as well as identify which areas cannot be left out of their investigations. This bibliometric analysis encourages the revision and consolidation of existing research directions in this field, as well as the exploration of new ones. The key scientific contributions of this study are the presentation of the biotechnology education and green chemistry issue, which is yet little studied as can be seen in the analysis, and its rising relevance to the scientific community to promote more studies and research on the subject.

Conclusion

There has been constant scientific work in chemistry education during the last 10 years. In line with the study institutions, nevertheless, only a few varied perspectives were documented. Hence, the focus of this research was to apply bibliometric analysis to examine the current trends of biotechnology research in education towards green chemistry over the previous decade (2012-2022). Using the 'title' search results, data was retrieved from Scopus-indexed documents. 420 completed papers from different research types were being used for extra assessment. The bibliometric review was carried out using traditional bibliometric indicators and two software applications (Harzing Perish and VOSviewer). This analysis uncovered three distinct kinds of articles generated, all of which are related to biotechnology, education, and green chemistry teaching. Articles make up 42 percent of all publications. The most frequent type of source is a journal (91 percent). Following that, the number of related articles increased.

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