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Review

Analyzing the Evolution of Research on Student Awareness of Solid Waste Management in Higher Education Institutions: A Bibliometric Perspective

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Abstract: Improper solid waste management (SWM) has resulted in an environmental and epidemiological catastrophe, emphasizing the urgency of SWM due to escalating solid waste generation. Over the past few decades, there has been significant growth in publications studying the relationship between SWM and the environment. Higher education institutes (HEIs) also have a social responsibility to promote public understanding of SWM and to increase awareness among students about SWM. A bibliometric analysis was conducted to provide an overview of research on student awareness of SWM in HEIs over the past 35 years. Data on publication output are identified based on the Scopus database (from 1989 to 2024). A total of 634 articles on SWM awareness and practices among students in HEIs were identified. VOSviewer was used to map the current studies and visualize the current trends in this area. The analysis of keywords used in the publications highlights recurring terms such as "recycling", "environmental awareness", and "waste management", indicating the primary research focus. The results show a significant increase in publications in this area over the last 35 years. China, the US, and the UK emerge as the countries with the highest number of publications with 115, 82, and 44 publications, respectively, where China alone contributed 18.14% of the total publications on the topic, with the Chinese Academy of Sciences and Tsinghua University being the leading institutions in this research field. The results also highlight the top researchers in the field of student awareness of SWM in HEIs. It identifies influential journals in this field, such as *Sustainability* (MDPI) and the *Journal of Cleaner Production* (Elsevier). Overall, this study provides valuable insights into the current state of research on student awareness of SWM in HEIs, identifying research hotspots. It serves as a valuable resource for academics and practitioners interested in this area. The findings of the study are intended to guide researchers planning to conduct further research on the issue.

Keywords: bibliometric analysis; higher education institutes; solid waste management; awareness; campus

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1. Introduction

The rapid progress of technology, economic growth, and urbanization has led to an unprecedented surge in waste production, posing significant health and safety risks on a global scale [1,2]. The shift in industrialization patterns and consumer-driven lifestyles has resulted in a substantial rise in both the quantity and quality of solid waste (SW), greatly

affecting the environment [2,3]. The World Health Organization (WHO) estimates that in 1900, there were 220 million people living in urban areas worldwide, generating less than 300,000 tons of SW per day [2]. Fast forward to 2000, with a staggering increase, with 2.9 billion people living in cities, accounting for 49% of the global population, and producing 3 million tons of SW per day. Predictions from the World Bank indicate that by 2025, the global amount of SW generated annually will skyrocket from 1.3 billion tons to a staggering 2.2 billion tons. Furthermore, urban cities in developing cities, particularly in Asia, are grappling with an alarming waste crisis, generating a whopping 790 million tons of waste alone, four times the amount produced in 1997 [4,5]. These worrisome statistics have spurred scientists across nations to explore effective solid waste management (SWM) strategies to establish a sustainable ecosystem [2,6].

SWM assumes a pivotal role in environmental infrastructure and urban development, aiming to reduce, recycle, and manage SW in order to protect environmental and human health and support sustainable economic growth [1,7,8]. The main operations of SWM include recycling, composting, and waste prevention, as well as landfill design, construction, and management [9]. SWM presents one of the greatest global development challenges. In addition to causing environmental and health damage, poor SWM also hinders a nation's progress towards achieving sustainable development [7,8]. Numerous studies on this topic have concentrated on various sides of SW, including waste generation [10], energy efficiency [11], plastic waste management [12,13], sustainable recycling [14], and environmental sustainability [12].

All the previous comprehensive studies have delved into mitigating the challenges posed by waste and have proposed solutions to solid waste problems, mainly employing a top–down method in situations where waste has already been generated. However, it is essential to recognize that waste does not emerge in isolation [2]. It is a product of human needs and desires in diverse scenarios. The chain of waste generation, disposal, and consumption is ultimately controlled by individuals who make conscious decisions regarding waste production or reduction [2].

Higher education institutions (HEIs) have emerged as significant contributors to waste generation in urban and rural areas [15–17]. Due to the size of university campuses, dense populations, and diverse range of domestic and scientific activities, they can be likened to "small cities" [18]. Recognizing this, it becomes imperative for HEIs to integrate sustainability principles into their operational and systemic frameworks, transforming their campuses into dynamic learning environments where students and faculty actively engage in hands-on learning, research, and experimentation [19]. Consequently, the development of more comprehensive SWM solutions becomes essential within the context of SD [8]. The policies of HEI concerning SWM and programs for SWM require student and staff involvement in identifying problems and planning solutions. It is crucial to acknowledge that HEIs, unlike other institutions, bear a unique responsibility to disseminate knowledge and train their communities to serve society. By instilling a sense of awareness and cultivating a sustainable culture through active participation in everyday activities, HEIs can effectively prepare future leaders to tackle daily challenges using sustainable approaches [16].

In today's increasingly polluted environment, possessing the knowledge of proper waste disposal techniques assumes paramount importance [20]. Increased awareness is pivotal in enhancing the likelihood of community backing for initiatives aimed at addressing and mitigating these environmental challenges [21]. Adopting effective SWM practices requires educating the community at large and fostering a sense of ownership and responsibility towards waste management. Creating awareness regarding SWM has the potential to transform people's attitudes towards waste, dispelling the notion that waste is simply garbage that should be discarded indiscriminately [8]. Previously, there was a prevailing belief that all types of waste could be indiscriminately disposed of in a single container [8,22]. It is essential for HEIs to establish a prominent model of sustainable management, actively striving to make a positive impact on society. Leaders in higher education bear significant responsibilities for effectively balancing financial, social, and

environmental objectives, as these aspects are frequently interconnected. It is crucial for them to recognize that the goals of HEIs, such as educating students and generating and disseminating knowledge, require substantial resources [23,24].

Although there is limited research on SWM, an initial study conducted by Karapantsios et al. [25] focused on analyzing the preconceptions of students regarding the urban environment and SWM in a small Greek city. The study aimed to assess students' awareness and interest in environmental issues, particularly in relation to everyday aspects of city life. In contrast, a recent study conducted by Mukhtar et al. [24] examined the knowledge and attitude of public and private school students in Lahore, Pakistan, specifically related to plastic pollution. The most recent bibliometric analysis published by Olabi et al. [26] focuses on medical waste management. This study examines the trends and patterns in research related to medical waste management, including topics such as disposal methods, environmental impact, and regulatory frameworks. However, it does not explicitly analyze the awareness aspect of medical waste management. Thus, there is currently no comprehensive study that explores the awareness of HEIs, particularly in the field of education and provides a holistic view by considering journal rankings, authors, universities, and countries.

This paper aims to bridge this gap by analyzing emerging trends in SWM research from 1989 to 2024. The main objective is to identify and explore the intersection between sustainability, SWM, and HEIs. The study specifically investigates the influence of student knowledge, environmental education, and behavior on SWM awareness, contributing a unique dimension to the existing literature. Additionally, this study aims to enhance the existing literature by developing rankings in the field of SWM through bibliometric analysis. Bibliometric analysis is a systematic method that identifies the most influential academic outputs and major trends in a field. In this study, bibliographic coupling is employed to determine the most influential journals, authors, universities, and countries. Visualization of Similarities Viewer software (VOSviewer version 1.6.20) is utilized to construct and visualize bibliometric networks.

2. Methodology

2.1. Study Boundary, Data Source, and Search Strategy

PRISMA principles were employed in this study's review of the recent literature [27]. We adhered to PRISMA principles without taking into consideration methods for meta-analysis. Bibliometric analysis is a valuable method for creating an extensive and repeatable database in systematic literature reviews [27]. It is essential to establish a clear scope for the study and offer a detailed explanation of the methodologies used to find relevant sources when conducting bibliometric analysis. The wide acceptance and effectiveness of bibliometric analysis can be attributed to its ability to provide a comprehensive overview of research areas, institutions, publications, and trends [28]. This method is widely used to examine and analyze extensive academic data with the aim of understanding the relationships among journal citations and summarizing the current or emerging landscape of a certain subject [29]. By employing bibliometric analysis and its indicators, researchers can build on previous studies and advance future research [30]. These characteristics have led to the widespread application of bibliometric techniques across various domains [31,32].

For the purpose of tracking trends and advancements in awareness of HEIs for SWM research, this research utilized bibliometric analysis. Data were collected from the Scopus database, which was selected due to its comprehensive coverage of academic publications across various fields [33–35]. Notably, Scopus provides approximately 20% more coverage than Web of Science (WOS), while the results from Google Scholar have variable levels of reliability [36–38]. The use of Scopus allowed for the inclusion of a large variety of publications to enhance the analysis. To conduct the literature search, particular keywords were used with the following query string: "(TITLE-ABS-KEY ((("Solid Waste Management" OR "SWM" OR "Waste Sorting" OR "Waste Separation" OR "Waste Minimization" OR "Zero Waste" OR "Recycling" OR "3Rs") AND ("Environmental Awareness" OR "Environmental

Attitudes" OR "Student* Awareness" OR "Student* Attitudes" AND PUBYEAR > 1988 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")). Additionally, the search was confined to the timeframe from 1989 to April 2024. The search strategy is shown in Figure 1.

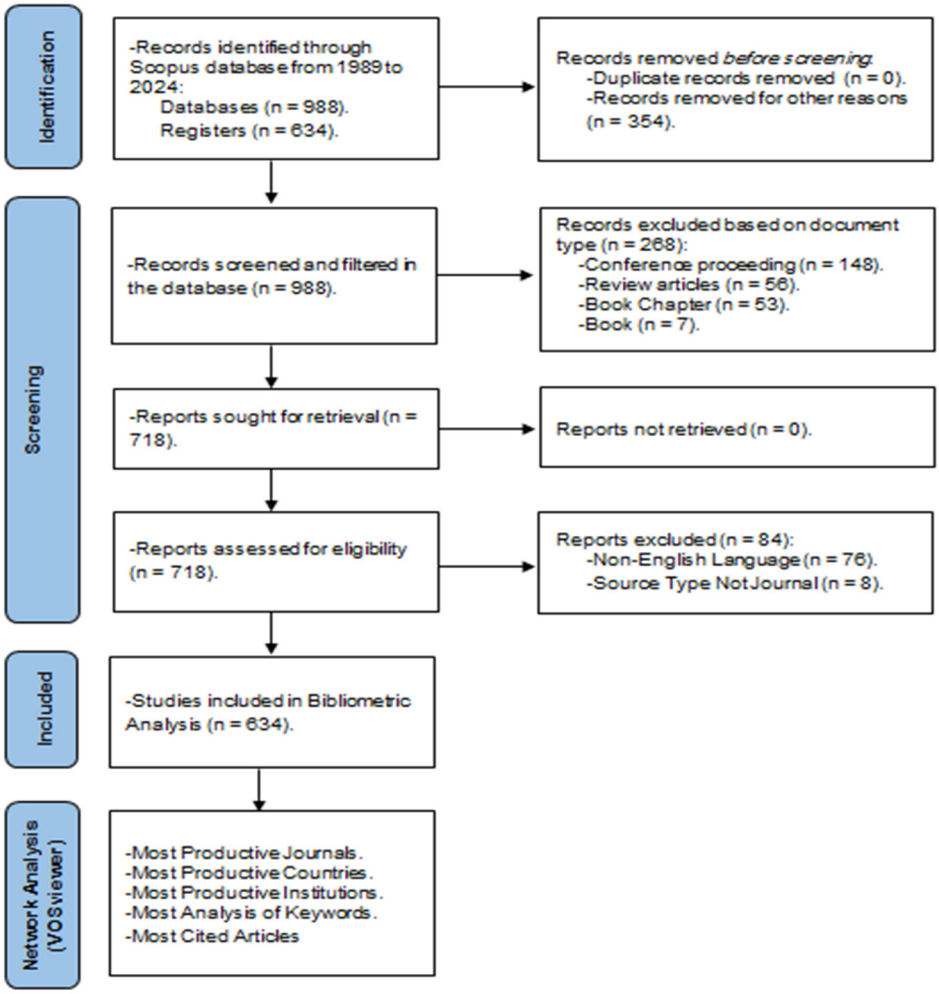

Figure 1. Flow diagram of the search methodology.

As shown in Figure 1, a collection of 988 documents was obtained, including articles, conference proceedings, review articles, book chapters, books, and conference reviews. After that, these documents were carefully refined by selecting only journal papers written in English. After filtering, 634 were selected as the final set.

2.2. Extracting and Filtering Data

The Scopus database provided the bibliometric data for this study, which were then stored in a Comma-Separated Values (CSV) file format. During the study's chosen process, rigorous filtering steps were implemented to ensure the accuracy and reliability of the data. These stages comprised a number of steps, including the identification and removal of duplicate records and the application of inclusion and exclusion criteria according to variables such as language, document type, and source. After the records were filtered, they were retrieved and underwent a comprehensive examination of each column, which included information such as affiliations, authors' names, source title, and publication year. Analyzing the keywords, abstracts, and titles allowed us to determine the article's overall quality. Any inaccurate or missing entries were carefully removed throughout the data filtering process, further honing the dataset in preparation for further research.

2.3. Data Analysis

Bibliometric research is increasingly adopting the technique of creating and visualizing bibliometric maps to aid in understanding. This approach simplifies the collection of literature and determines connections between chosen articles. We utilized the VOSviewer software for data processing in order to analyze the obtained results and develop an understanding of bibliometric trends. VOSviewer is an open-source program that provides user-friendly features for displaying and networking bibliometric data. In contrast to other software applications, such as Bib Excel, SciMAT, Gephi, and CiteSpace, it offers distinct capabilities [39,40]. VOSviewer software was selected for data processing and analysis due to its ability to handle large networks and incorporate text-mining features [34]. To help with the identification of connections, trends, patterns, and trends within the literature, bibliometric maps were created using VOSviewer to graphically represent the interconnections among the chosen publications [41].

Five main areas of analysis were focused on in this study: the author keywords utilized in the papers, the countries, the institutes, the scientific journals in which the articles were published, and the scientific publications in which the articles were published. These aspects are essential to bibliometric studies because they provide insightful information on the state of the field [42–44]. The analysis incorporated key metrics such as average normalized citations, documents, and the total number of links. These metrics are essential for evaluating the paper's exposure and effect [45].

3. Results and Discussion

3.1. Trends in Publications

All articles in this study were categorized into eight categories, as shown in Figure 2a. Approximately 64.17% of all publications are of the type "article", making it the most prevalent type. The remaining publication types consist of "Conference Proceeding" (14.98%), "Non-English Language" (7.89%), and Others (e.g., "Not Journal", "Review Article", "Book Chapter", "Book", and "Conference Review)". Since "Article" was the predominant publication type, the other categories were excluded from subsequent analysis.

An analysis was conducted on the number of publications related to student awareness of SWM in HEIs from 1989 to April 2024, as illustrated in Figure 2b. An increase in the number of articles over the years was observed. A total of 634 documents were identified using the keywords "HEIs", "SWM", and "student awareness". The number of publications was significantly low in the early years, which can be attributed to the limited focus on this topic initially. However, publications on student awareness of SWM in HEIs started gaining more importance from 2013 onwards. There were just 40 Scopus documents published between 1989 and 1999. The 2000s saw a slow increase in growth, but since 2009, it has accelerated significantly. Additionally, interest in student awareness of SWM in HEIs increased to 295 documents over the past decade. These data describe an emerging academic field that is just beginning to grow.

In 2024, 28 papers were published in less than four months, indicating that over 84 articles may be published this year. In 2023, academics published 81 articles in this field, which is a significant increase compared to previous years. This indicates the growing interest among researchers and students regarding proper SWM. The increase in the number of publications can be attributed to efforts to promote environmental awareness and sustainability in this field within HEIs, as well as advancements in SWM technology [46]. It is likely that progress in this field will continue in the coming years.

The growing interest in researching student awareness of SWM in HEIs is due to the increased importance of the topic in public discourse concerning waste in most regions. Furthermore, universities are considered university cities due to their size and daily influx of people, resulting in the production of a large amount of waste, including paper and even demolition waste [18]. The necessity to increase student awareness of SWM is emphasized, particularly regarding the relationship between educational objectives and societal require-

ments regarding preparing youth for greater awareness of their environment and the need for adequately trained specialists.

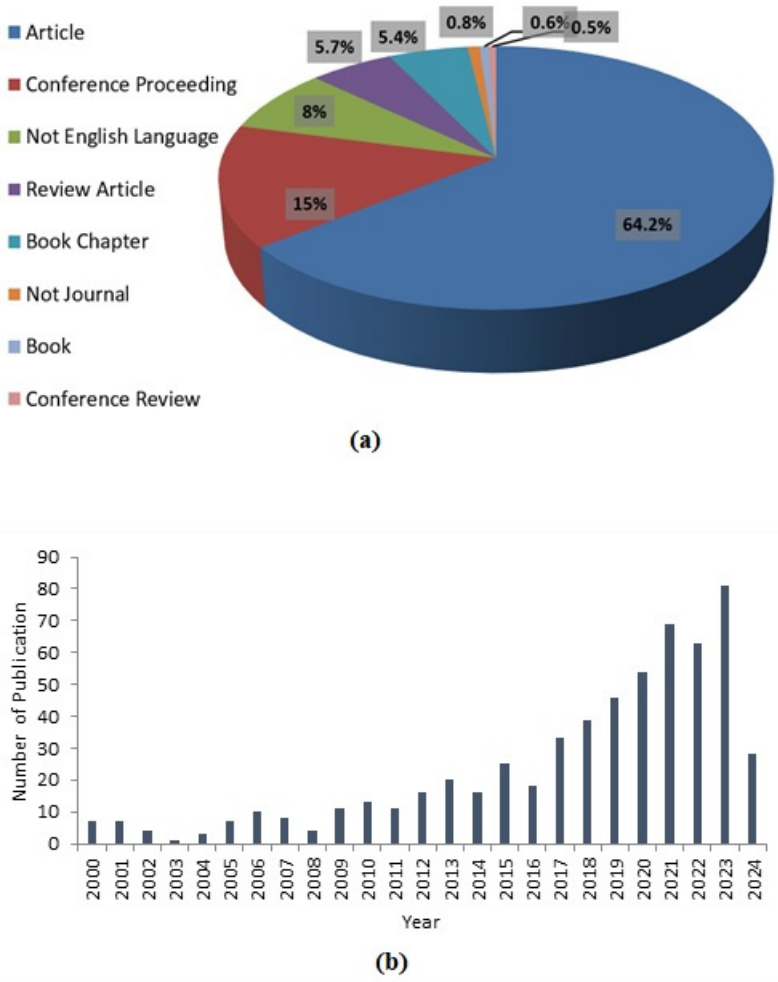

Figure 2. (**a**) document type percentage of reports for the student awareness of SWM in HEIs research; (**b**) publication trends for the student awareness of SWM in HEIs based on Scopus data until April 2024 (n = 634).

In order to illustrate various study areas, this study has examined the distribution of publications about student awareness of SWM at HEIs. The research documents and the areas of research were examined to identify publication patterns. The findings, illustrated in Figure 3, reveal the primary study areas covered over the last 35 years. Environmental science constitutes approximately 27.8% of the research publications, making it the most prevalent domain. Social sciences follow at 14.9%, engineering at 9.96%, energy at 9.27%, and business, management, and accounting at 7.72%. Other fields such as economics, econometrics, and finance, computer science, materials science, and others contribute to smaller proportions of research publications on student awareness of SWM in HEIs. It is worth noting that Scopus, a popular research database, does not have a specific subject area dedicated to student awareness of SWM in HEIs. This indicates that research in this field is spread across multiple subject areas. However, the analysis reveals that the primary thematic area for this research is environmental sciences, which aligns with the broader focus on environmental issues. Since environmental sciences have connections to other disciplines, the Scopus database includes several subject domains, suggesting a multidisciplinary approach to this subject. In the future, this type of research will continue to expand.

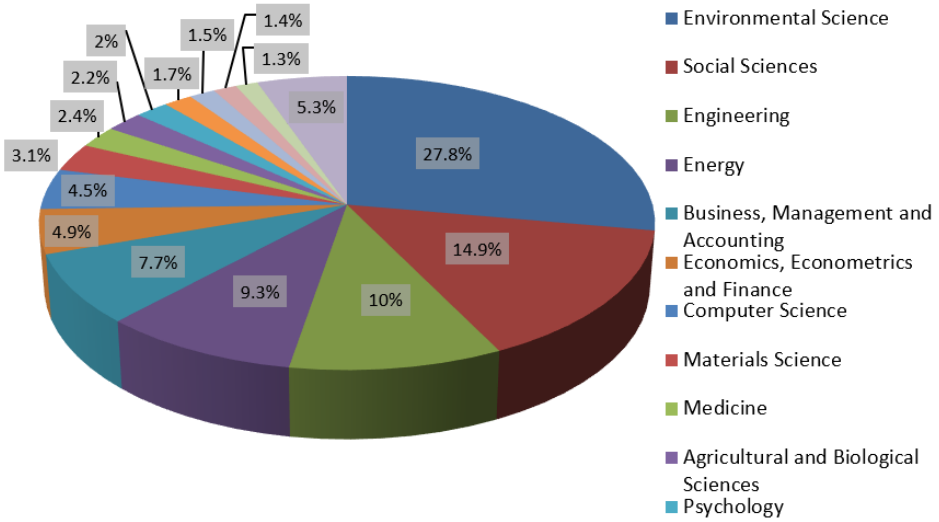

Figure 3. Scopus documents categorized by subject.

Based on Figure 3, there has been a progressive transformation in the domain of study. It has shifted from emphasizing "environmental science", "social science", "engineering", and "energy" in the beginning to adopting a multidisciplinary approach. Numerous academic disciplines, including "Material Science", "Economics, Econometrics, and Finance", "Business, Management, and Accounting", "Computer Science", "Medicine", and other pertinent topics, are integrated into this multidisciplinary approach. As a result, this shift has led to a notable increase in research activity concerning student awareness of SWM in HEIs.

3.2. Leading Journals for Research on the Student Awareness of SWM in HEIs

The most cited journals for student awareness of SWM in HEIs were found in the Scopus database. Table 1 lists the 13 eminent journals in this subject along with their total link strength (TLS), SCImago Journal Rank (SJR), article count, H-index, and citation count.

Table 1. The top 13 journals in student awareness of SWM in HEIs research.

Source Journal	TLS	Number of Publications	Total Citations	H-Index	SJR
Sustainability (Switzerland)	148	48	771	169	0.672
Journal of Cleaner Production	123	36	2454	309	2.058
Resources, Conservation and Recycling	102	27	2369	196	2.770
Waste Management	67	21	797	220	1.734
Journal of Environmental Management	92	12	704	218	1.678
Environment and Behavior	48	8	1482	142	1.572
Environmental Science and Pollution Research	4	7	286	154	0.944
Journal of Material Cycles and Waste Management	2	7	58	60	0.661
International Journal of Sustainability in Higher Education	4	6	237	77	0.830
Psyecology	29	6	14	80	0.791
Science of the Total Environment	7	6	488	353	1.998
Environment, Development and Sustainability	7	5	67	82	0.889
Sustainable Production and Consumption	20	5	100	76	2.359

The 634 articles searched in this study were published in 159 various journals. The top 14 journals, or around 32.65% of the 159 journals, are shown in Table 1 based on the number of publications. In terms of the number of papers published, three significant journals in the field of student awareness of SWM in HEIs were ranked in the top three. Among them, *Sustainability* (Switzerland) published 48 articles (7.57%) and was ranked

first in terms of publication number; in addition, the *Journal of Cleaner Production* was ranked second in terms of publication number. In terms of publications examining student awareness of SWM in HEIs, the journal of *Resources Conservation and Recycling* ranked third, having published fewer papers annually than *Sustainability* (Switzerland) and the *Journal of Cleaner Production*. With 17.51% of the total number of publications coming from these three journals, it is likely that these are the most important journals that have been researching student awareness of SWM in HEIs over the past decades.

The *Journal of Cleaner Production* (2454 citations), *Journal of Resources*, *Conservation*, *and Recycling* (2369 citations), *Journal of Environment and Behavior* (1482), *Waste Management Journal* (797 citations), and *Sustainability* (Switzerland) (771 citations) are the top five journals in the cited domain in terms of citation count. *Sustainability* (Switzerland) has 48 articles, 771 citations, 169 H-indexes, and 0.672 SJR, making it the most prolific in terms of student awareness of SWM at HEIs. Even though most journals have a higher H-index and SJR value, they have less impact in the area mentioned because they need more citations. These results enable researchers to select journals that might be a good fit for publishing their next articles. Journals with five or more articles published in this area of study between 1989 and April 2024 were chosen as the primary sources. Of the sources that were found, 14 satisfied these requirements, as illustrated in Figure 4. The research on students' awareness of SWM in HEIs may be mostly found in these 14 journals, which are also crucial to the area of study. Scientific journals help research findings get out there by advising scientists on the best media and platforms to use when sharing their findings [47].

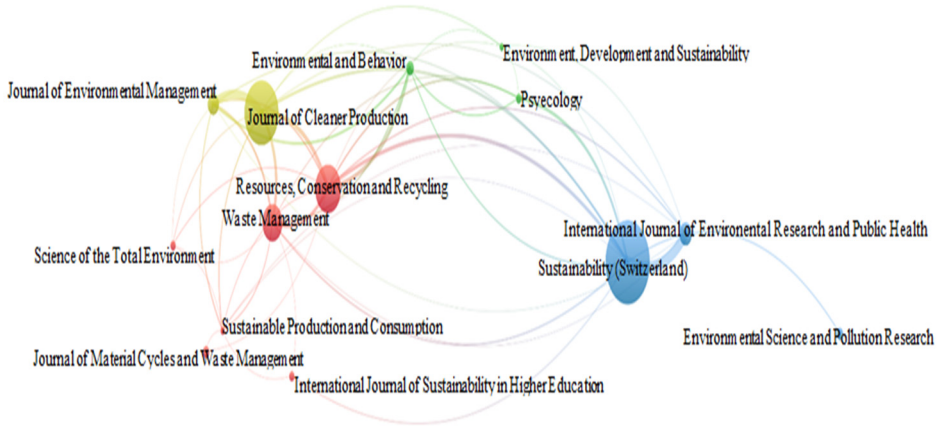

Figure 4. Co-occurrence map of journals from 1989 to April 2024 that include more than five articles related to student awareness of SWM at HEIs.

Over the past 35 years, the journals displayed in Figure 4 have made a significant contribution to research on student awareness of SWM at HEIs. These findings allow researchers to identify potential journals to submit their work for publication. Nine journals with an H-index > 142 are among the top fourteen journals. Additionally, ten journals are included in Scopus quartile 1, and three journals are situated in Scopus quartile 2. In addition, the wide variety of sources indicates the great interest of editors in this area of study.

By concentrating on published documents, we have found that there are five key sources that have made a significant number of documents available in the field of research under consideration. To provide a clear overview of the publication status of research on student awareness of SWM in HEIs, this study conducted an analysis of the publication history of the top five source journals based on a dataset of 634 articles, as illustrated in Figure 5. These journals are as follows: *Sustainability* (Switzerland) (48), *Journal of Cleaner Production* (36), *Resources Conservation and Recycling* (27), and *Waste Management* (21). The first paper on the application of student awareness of SWM in HEIs was published in *Waste Management* in 1994.

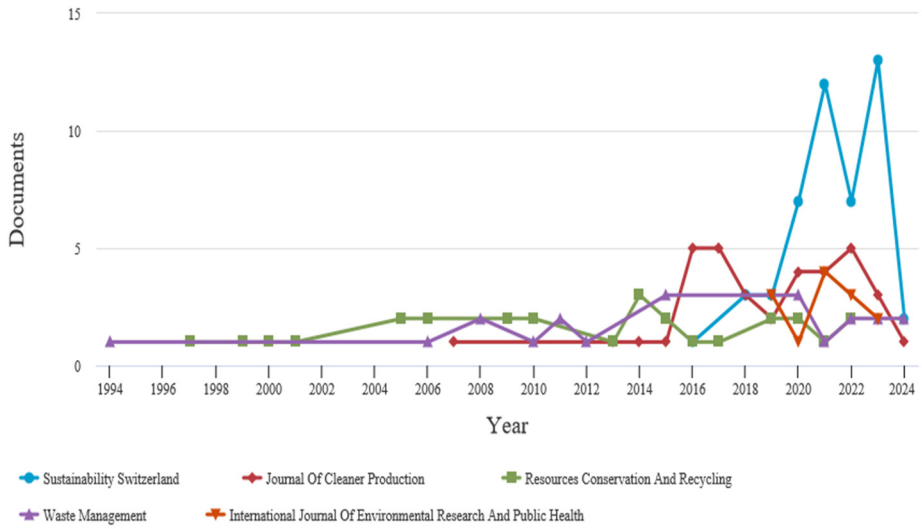

Figure 5. Publication statistics on the student awareness of SWM in HEIs (Data derived from Scopus).

Furthermore, it is worth noting that, as of 2016, *Sustainability* has gained more prominence compared to the other top five journals, exhibiting a consistent and significant rise in the number of publications per year on a global scale. In fact, it surpassed the *Journal of Cleaner Production*, which published just three publications in this field, with a peak of 13 documents in 2023. It is important to highlight that *Sustainability* started publishing in this field in 2016, whereas the *Journal of Cleaner Production* began publishing earlier, in 2009. Moreover, the number of related studies published in *Waste Management* and *Resources Conservation, and Recycling* has steadily increased since 2014.

Notably, the publication trends depicted in Figure 5 closely correlate with the respective journals' annual total number of publications.

3.3. Country Collaboration Network for the Student Awareness of SWM in HEIs

A total of 634 studies examining the awareness of SWM among students in HEIs were analyzed in this research. These studies were sourced from 82 countries, utilizing the full counting statistical method, which encompassed information from all the authors involved in each article. Research collaboration plays a vital role in generating novel scientific knowledge [48]. There are many different forms of research collaborations, but the most common ones involve authors, institutions, and other countries working together [48]. A network diagram was created for this study in order to pinpoint the countries with the highest degrees of influence and collaboration on the subject. The network diagram, which was made with VOSviewer, shows the countries as nodes with corresponding labels. The lines that link the nodes represent the collaborative and connected efforts between countries. The intensity of the collaboration is reflected in the thickness of the lines. Furthermore, each node's size and font size reveal how many citations it has received from that country. Countries with a greater number of articles authored by their researchers are represented by larger labels and nodes. Furthermore, a link is illustrated between the nodes representing those countries to indicate co-authorship between organizations across various countries [49].

Figure 6 illustrates the network of international co-authorship among countries, revealing that 15 countries are interested in researching student awareness of SWM at HEIs.

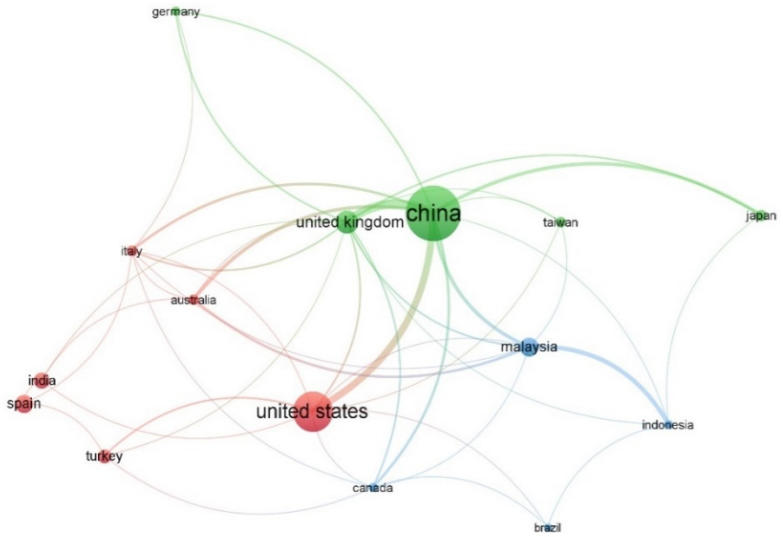

Figure 6. Network visualization of the major countries in the study investigation of SWM awareness among students in HEIs.

Figure 6 displays the statistics on the number of articles in the top 15 countries. The top five countries in terms of articles are China, the US, the UK, Malaysia, and Spain, as seen in Figure 6. Table 2 presents an overview of the publishing characteristics of the top 15 countries that have published more than 15 papers about student awareness of SWM in HEIs. These countries have played a significant role in advancing the field. Among them, China stands out as the most productive country, having published 115 articles, which accounts for 18.14% of the total publications. The United States follows closely behind with 81 articles (12.93%), while the United Kingdom has contributed 44 articles (6.94%). Malaysia and Spain also demonstrate noteworthy contributions, with 36 articles (5.68%) and 35 articles (5.52%), respectively. The research output of these five countries highlights their substantial involvement and valuable insights into the study of student awareness of SWM in HEIs. The prominence of these countries in publishing articles on student awareness of SWM in HEIs may be attributed to either a specific scientific interest in the topic or their strong scholarly capabilities.

Table 2. Leading 15 countries through collaboration and publishing on student awareness of SWM in HEIs (ranked by TLS).

Country	TLS	Number of Publications	Total Citations	Avg. Citations	Avg. Norm. Citations	Avg. Publication Year
China	40	115	3730	32.43	1.39	2020
United States	18	81	4379	54.06	1.08	2011
United Kingdom	27	44	2693	61.20	1.42	2015
Malaysia	18	36	1236	34.33	1.45	2017
Spain	3	35	1039	29.69	1.02	2017
India	4	31	253	8.16	0.67	2018
Turkey	5	27	541	20.04	0.82	2020
Japan	7	21	343	16.33	0.90	2014
Italy	11	20	548	27.40	1.32	2019
Taiwan	4	20	418	20.90	0.91	2018
Australia	10	19	1012	53.26	2.14	2019
Canada	10	17	739	43.47	1.03	2015
Germany	5	17	475	27.94	1.02	2017
Indonesia	9	17	177	10.41	1.26	2021
Brazil	3	15	356	23.73	0.72	2019

In terms of citations, including both citations and self-citations from other sources, several countries have emerged as significant contributors to the research on student awareness of SWM in HEIs. The United States leads with 4379 citations, followed by China with 3730 citations, the United Kingdom with 2693 citations, Malaysia with 1236 citations, and Spain with 1039 citations. These numbers suggest that these countries hold considerable influence in the field of SWM awareness among students in HEIs. Furthermore, when considering the average number of citations per article, the UK comes in first place with 61.2 citations per article, the US comes in second with 54.06 citations per article, and Australia comes in third with 53.26 citations per article. These figures indicate that research conducted in these countries tends to receive higher-than-average citation rates, highlighting the quality and impact of their contributions.

Analyzing the cooperation network among researchers, it becomes evident that China, the UK, the US, Malaysia, and Italy exhibit extensive collaboration links. The collaboration network depicted in Figure 6 highlights the strong connections between researchers from these countries and their neighboring nations. China, the US, and the UK, in particular, hold prominent positions within their respective countries' cooperation networks, indicating their significant contributions and collaborations in the study of student awareness of SWM in HEIs.

To identify the leading universities conducting research on student awareness of SWM, a map was created based on the 634 publications available in the Scopus database. However, the original data provided affiliations in terms of departments or colleges rather than specific universities or research institutes. Therefore, it was necessary to restructure this information to accurately represent the universities or research institutes involved, as illustrated in Figure 7.

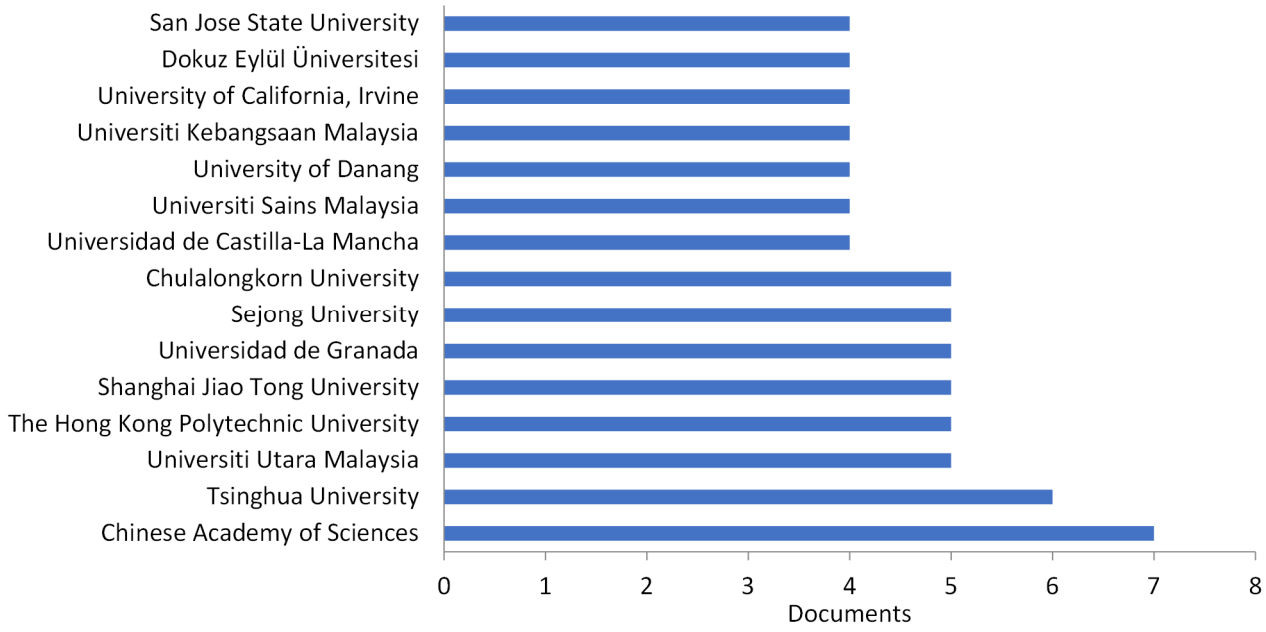

Figure 7. Top 15 universities according to authors' affiliation (4 or more articles).

As shown in Figure 7, it is observed that in terms of the affiliation of the works developed by the various authors, the institutions that stand out the most are the Chinese Academy of Sciences (seven documents), Tsinghua University (with six documents), Universiti Utara Malaysia (five documents), The Hong Kong Polytechnic University (five documents), Shanghai Jiao Tong University (five documents), Universidad de Granada (five documents), Sejong University (five documents), Chulalongkorn University (five documents), Universidad de Castilla-La Mancha (four documents), Universiti Sains Malaysia (four documents), University of Danang (four documents), Universiti Kebangsaan Malaysia

(four documents), University of California, Irvine (four documents), Dokuz Eylül Üniversitesi (four documents), and San Jose State University (four documents).

These institutions are in line with the countries that have made noteworthy contributions, illustrating the close relationship between connections and place of birth in this field of study. This pattern can be explained by the countries' encouragement of innovation and scientific research in SWM in HEIs, as well as the existence of networks of cooperation between institutions within each nation. In HEIs, this kind of international cooperation is essential for expanding research and raising student understanding of SWM.

3.4. Co-Citation Authors Network in HEIs Students Awareness of SWM

Co-citation network analysis is a useful scientific method for mapping the existing literature in an organized manner. It allows for the identification of articles that are consistently cited and have similar themes [28]. This analytical approach is essential to identifying the underlying conceptual framework and themes within a particular study area. In this study, we carried out a comprehensive examination of co-citation patterns among authors using the VOSviewer software's co-citation network feature. Using this approach allowed us to obtain important insights into the themes and interconnectedness of the relationships among the mentioned works. Table 3 presents this thorough comprehension of the state of research in our area of study.

Table 3. Co-occurrence map of researcher collaboration from 1989 to 2024.

Author	Number of Publications	Author	Citations
Han, H.	5	Debrah, J.K.	120
Nixon, H.	4	Boca, G.D.	103
Saphores, J.D.M.	4	Ongondo, F.O.	91
Barr, S.	3	Tangwanichagapong, S.	82
Best, H.	3	Thapa, B.	66
De-la-Torre, G.E.	3	Alsaati, T.	47
Islam, M.T.	3	Fagnani, E.	45
Li, J.	3	Kaplowitz, M.D.	40
Poon, C.S.	3	Bashir, M.J.	23
Agissova, F.	2	Hao, M.	18

A small number of specialist authors acquire a disproportionate quantity of attention and information, whereas a larger number of transient authors produce comparably fewer articles. This phenomenon is known as the Matthew Effect, as highlighted by Grandjean et al. [50]. This effect represents an unequal distribution of scientific production, in which a small number of authors become well known and have more influence in the scientific community, but a larger group of authors may face challenges in attaining a similar level of visibility or impact. When interpreting bibliometric data, it is crucial to acknowledge and take into account these biases.

The analyzed dataset consists of 634 publications, encompassing the work of 538 distinct authors, resulting in an average of 0.48 authors per document. Notably, some authors have contributed to multiple publications, indicating a particular interest in this research domain. In Table 3, we present the relevant information regarding the most influential authors, including the number of documents they have published and the number of citations their work has received. It is important to acknowledge that this methodology unintentionally amplifies the Matthew Effect, as it favors authors with a higher volume of publications. Within this context, our analysis identifies ten primary authors who have published a minimum of two papers within this specific research field. Among them, Han emerges as the most prolific author, with five documents, followed by Nixon and Saphores, each with four documents. Interestingly, these authors are not listed as authors in any of the selected publications. The remaining authors have contributed three documents each, except for the last author, who has two documents to their name. Furthermore, in

terms of citation impact, we observe that Debrah has accumulated 120 citations, making them the most cited author, trailed closely by Boca with 103 citations and Ongondo with 91 citations. These findings indicate a collaborative and multi-author approach within the field, although a few authors assume a more prominent role in terms of publication output.

3.5. Most Influential Publications in Student Awareness of SWM in HEIs Research

Citation analysis is a crucial method used in scientific mapping to establish intellectual linkages between articles, especially when one paper references another [28]. This technique aids in the analysis of citation patterns and trends and helps discover important research publications within a certain academic topic [51]. Consequently, we performed a citation analysis on the articles being investigated. Based on information gathered from the Scopus database, we have compiled the top 18 articles that have earned the most citations in Table 4. It is important to note that the rating of these publications is exclusively based on whether they meet the criteria established by the Scopus database.

The following data provide an overview of the top three research projects, as found by a search of the Scopus database: The most cited research, with 120 citations, is "Raising awareness on solid waste management through formal education for sustainability: A developing country evidence review". It was published in the *Journal of Recycling* in 2021. The paper highlights the multifaceted nature of SWM and its significance in developing countries due to urban growth. It emphasizes the knowledge gap between younger and older generations, which leads to ecological issues and unsustainable development. An analysis of SWM-related environmental knowledge, attitudes, awareness, and practices in developing nations was carried out. The study found that secondary and university students are well aware of environmental issues and have favorable views about the environment. However, there is a lack of practical training for teachers to assist students in putting SWM methods into practice. The low environmental knowledge among students is attributed to the limited practical experience of teachers in SWM with environmental sustainability. The study also revealed a correlation between teachers' and students' knowledge and attitudes towards SWM. Additionally, there were differences in awareness, attitudes, and practices related to SWM based on education and age. The majority of developing nations lack environmental education because there are insufficient practical environmental curricula that would enable instructors to address contemporary environmental challenges and encourage cleaner manufacturing and sustainable development. In developing nations, environmental sustainability education has to be incorporated into higher education institutions at all levels in order to close the knowledge gap that exists between younger and older generations about SWM.

The second-most-cited work has received 103 citations. In 2019, Boca and Saraçlı [52] published a paper titled "Environmental education and students' perceptions for sustainability" in the *Journal of Sustainability* in 2019. This author focuses on the importance of environmental education and its impact on changing attitudes and behaviors towards sustainability. The study aims to examine the relationship between environmental behavior, attitude, and perception among university students from different specialized fields, namely economics, mechanical engineering, and electrical engineering. The survey was conducted at the North Center University of Baia Mare, with a sample size of 358 students. The study highlights the interconnection between the environment and education in fostering sustainable development. It emphasizes the potential influence of educational institutions on defining and implementing effective environmental education programs. A Likert scale was used to collect data on students' environmental behaviors, attitudes, perceptions, and education. The findings reveal that students who receive academic education are actively engaged in environmental protection activities such as volunteering, raising awareness, participating in environmental initiatives, and recycling materials. They also show a preference for new and greener alternative energy sources. Statistical analysis, including *t*-tests, indicates that there is no significant difference in the level of perception regarding the importance of environmental education among the students. Furthermore,

correlation analysis demonstrates a positive relationship between perception, attitude, and behavior variables.

"Greening academia: Use and disposal of mobile phones among university students", which was published in the *Journal of Waste Management* in 2011 by Ongondo and Williams [53], is the third most cited study. It explores the environmental and economic challenges associated with university students' usage and disposal of mobile phones. The researchers conducted a survey among students at five UK universities and implemented a pilot mobile phone takeback program at one university. The findings revealed that many students replace their phones frequently, with approximately 60% of the replaced phones being stockpiled by students as backup devices rather than being recycled or reused. The study estimated that in the UK higher education sector alone, there are 3.7 million stockpiled phones. The research also found that while students are generally aware of mobile phone recycling and reuse services, their utilization of these services is relatively low. The study suggests that recycling behaviors for other materials, such as paper and glass, do not significantly influence students' disposal actions for mobile phones. However, students who frequently recycle other materials are more likely to participate in mobile phone takeback services. This study provides insights into students' behavior and the challenges associated with managing electronic waste in HEIs, particularly regarding mobile phone disposal.

The top 18 highly cited studies in the field of student awareness of SWM in HEIs are listed in Table 4. These studies aim to promote sustainability and the establishment of environmentally friendly, green universities. They recognize the importance of educating and raising awareness among students regarding SWM. By increasing students' education and awareness about SWM, these studies strive to contribute to creating a more sustainable future and achieving environmentally conscious campuses.

Table 4. Details of article citations.

Year	Document Title	Source Title	Citations	First Authors	Reference
2021	Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review	*Recycling*	120	Debrah, J.K.	[54]
2019	Environmental education and student's perception, for sustainability	*Sustainability*	103	Boca, G.D.	[52]
2011	Greening academia: Use and disposal of mobile phones among university students	*Waste Management*	91	Ongondo, F.O.	[53]
2017	Greening of a campus through waste management initiatives: Experience from a higher education institution in Thailand	*International Journal of Sustainability in Higher Education*	82	Tangwanichagapong, S.	[55]
1999	Environmentalism: The relation of environmental attitudes and environmentally responsible behaviors among undergraduate students	*Bulletin of Science, Technology & Society*	66	Thapa, B.	[56]
2020	Level of sustainability awareness among university students in the Eastern province of Saudi Arabia	*Sustainability*	47	Alsaati, T.	[57]
2017	Waste management plan for higher education institutions in developing countries: The Continuous Improvement Cycle model	*Journal of cleaner production*	45	Fagnani, E.	[58]
2009	Garnering input for recycling communication strategies at a Big Ten University	*Resources, Conservation and Recycling*	40	Kaplowitz, M.D.	[59]
2020	Appraisal of student's awareness and practices on waste management and recycling in the Malaysian University's student hostel area	*Journal of Material Cycles and Waste Management*	23	Bashir, M.J.	[60]
2020	Waste separation behaviour of college students under a mandatory policy in China: A case study of Zhengzhou City	*International Journal of Environmental Research and Public Health*	18	Hao, M.	[61]

Table 4. *Cont.*

Year	Document Title	Source Title	Citations	First Authors	Reference
2014	Sustainability and green IT education: Practice for incorporating in the Australian higher education curriculum	*The International Journal of Sustainability Education*	15	Issa, T.	[62]
2017	Students' attitudes to solid waste management in a Nigerian university: Implications for campus-based sustainability education	*International Journal of Sustainability in Higher Education*	13	Ifegbesan, A.P.	[63]
2017	The engagement of students in higher education institutions with the concepts of sustainability: A case study of the University of Northampton, in England	*Resources*	12	Cleverdon, L.	[64]
2021	Generation patterns and consumer behavior of single-use plastic towards plastic-free university campuses	*Chemosphere*	10	Nguyen, X.C.	[65]
2021	Plastic waste sorting intentions among university students	*Sustainability*	7	Aikowe, L.D.	[66]
2021	College students' willingness to separate municipal waste and its influencing factors: A case study in Chongqing, China	*Sustainability*	6	Yang, X.	[67]
2023	College students' attitude towards waste separation and recovery on campus	*Sustainability*	6	Qu, D.,	[68]
2021	Students' Awareness and Attitudinal Dispositions to E-Waste Management Practices at a Zimbabwean University	*Journal of Information Policy*	5	Maphosa, V.	[69]

3.6. Primary Research Topics for the Student Awareness of SWM in HEIs Research

A scientific paper's keywords serve as a synopsis of the study that was carried out. Through the analysis of these keywords, valuable understanding regarding the primary subject matter of the article can be obtained, and it aids in the identification of areas requiring further investigation. This expectation arises from the anticipated association between the selected keywords. The frequency of co-occurrence amongst the keywords can be utilized to establish this relationship [70,71]. By using keyword cluster analysis, it is possible to find a cohesive body of study that focuses on particular subjects and shares common themes. Consequently, this methodology facilitates the examination of research trends [27,70,72–74].

In this research, we performed a keyword co-occurrence analysis using VOSviewer to investigate research on student awareness of SWM in HEIs. The analysis utilized a comprehensive counting method. In total, 34 of these keywords were discovered to co-occur in the research after examining the keyword frequency in 634 articles from the Scopus database. Figure 8 presents a network visualization that demonstrates the co-occurrence patterns of keywords in articles that focus on student awareness of SWM in HEIs.

The co-occurrence patterns of the components in a network diagram are shown in Figure 8. The keyword co-occurrence analysis revealed the presence of six distinct clusters, each denoted by a different color, indicating their similarities within the research field. Six separate clusters were found using the keyword co-occurrence analysis; each cluster was colored differently to indicate how similar they were to one another within the study topic.

Each cluster, represented by nodes of certain colors, represents a different topic of study within the student awareness of SWM in HEIs. The size of nodes corresponds to the occurrence frequency of the keywords, with larger nodes denoting higher frequencies. The strength of the correlations between the items is shown by the thickness of the connection lines.

The top 37 keywords are included in Table 5, with the terms listed in descending order of TLS. A thorough scientific investigation was conducted to calculate the ranking of these keywords, accounting for many aspects such as the frequency of their occurrence, the number of links directed towards each keyword, and the cumulative link strength. The student awareness of SWM in HEIs is characterized by several prominent features. Among

the top 15 keywords, the most notable features include "environmental awareness", "waste management", "sustainability", and "environmental attitudes". These keywords highlight the key concepts and themes associated with student awareness of SWM in HEIs.

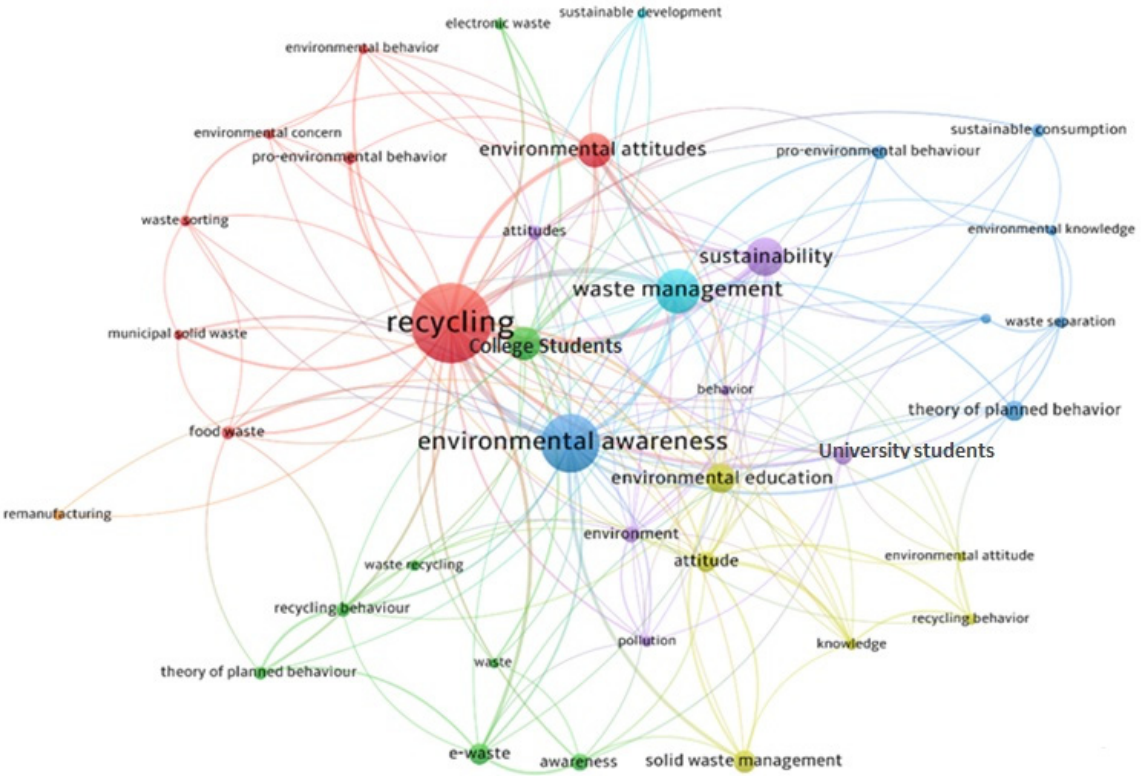

Figure 8. Author keyword co-occurrence clustering in a network visualization.

In terms of link strength, the keyword "recycling" exhibits the highest value of 96, indicating its strong association with other keywords in the network. "Environmental Awareness" follows closely with a link strength of 62, while "Waste Management" demonstrates a link strength of 47. These link strengths signify the degree of interconnectedness and relevance of these keywords within the network. Taken together, these keywords provide insights into the intellectual origins and foundations of student awareness of SWM in HEIs, shedding light on the important topics, concerns, and perspectives within this field of study.

Figure 8 and Table 5 illustrate the top 15 keywords in the Scopus database: "recycling" (16.44%), "environmental awareness" (10.68%), "waste management" (7.46%), "sustainability" (5.93%), "environmental attitudes" (5.25%), "environmental education" (4.07%), "solid waste management" (2.9%), "e-waste" (2.71%), "attitude" (2.54%), "theory of planned behavior" (2.54%), "university students" (2.2%), "awareness" (2.03%), "environment" (1.86%), "attitudes" (1.53%), and "pro-environmental behavior" (1.53%).

In this study, the Scopus database was used to analyze a set of keywords associated with student awareness of SWM in HEIs. The top 15 frequently used keywords in studies related to this topic were identified. The most used keywords include "recycling", which highlights the importance of recycling waste materials. "Waste management" and "solid waste management" emphasize effective waste management practices. "Environmental awareness" and "awareness" indicate the need for environmental consciousness and understanding. "College students" and "university students" point to the involvement and role of students in SWM initiatives. "Sustainability", "sustainable development", and "sustainable consumption" underscore the long-term viability and preservation of resources. "Education" highlights the significance of educational institutions in promoting awareness of SWM. "Attitude" and "environmental attitudes" imply the importance of attitudes and

perceptions towards solid waste management practices. "pro-environmental behavior", "environmental behavior", and "behavior" represent the behavioral aspects related to waste management. "Theory of Planned Behavior" refers to a psychological theory that explains behavior change. "Food waste", "e-waste", "electronic waste", "waste", "solid waste", "pollution", and "municipal solid waste" are specific types or forms of waste. "Waste recycling", "waste separation", and "waste sorting" highlight specific waste management practices.

Table 5. The top 37 keywords (ranked using TLS) from the student awareness of SWM in HEIs research.

Keywords	Cluster	TLS	Occurrence	% Occurrence	Average Citations	Average Publication Year
Recycling	1	96	97	16.44	34.68	2015
Environmental Awareness	3	62	63	10.68	27.57	2018
Waste Management	6	47	44	7.46	30.39	2018
Sustainability	5	39	35	5.93	24.29	2018
Environmental Attitudes	1	24	31	5.25	45.23	2016
Environmental Education	4	25	24	4.07	23.63	2019
Solid Waste Management	4	13	17	2.90	15.82	2015
E-Waste	2	17	16	2.71	66.81	2018
Attitude	4	24	15	2.54	53.87	2016
Theory Of Planned Behavior	3	11	15	2.54	26.07	2021
University Students	5	16	13	2.20	19.69	2017
Awareness	2	10	12	2.03	19.92	2019
Environment	5	16	11	1.86	25.45	2016
Attitudes	5	12	9	1.53	84.89	2012
Pro-Environmental Behaviour	3	9	9	1.53	26.56	2019
Recycling Behaviour	2	13	9	1.53	69.78	2015
Food Waste	1	11	8	1.36	15.50	2020
Pro-Environmental Behavior	1	6	8	1.36	70.88	2019
Sustainable Consumption	3	5	8	1.36	67.38	2018
Theory Of Planned Behaviour	2	10	8	1.36	36.75	2019
Electronic Waste	2	6	7	1.19	35.86	2016
Knowledge	4	15	7	1.19	9.29	2014
Pollution	5	12	7	1.19	47.43	2018
Recycling Behavior	4	8	7	1.19	46.29	2013
Waste Recycling	2	4	7	1.19	63.14	2015
Waste Separation	3	6	7	1.19	5.57	2022
Waste Sorting	1	7	7	1.19	3.00	2022
Behavior	5	10	6	1.02	44.17	2015
College Students	3	8	6	1.02	8.00	2020
Environmental Attitude	4	5	6	1.02	23.17	2019
Environmental Behavior	1	8	6	1.02	41.33	2014
Environmental Concern	1	8	6	1.02	20.00	2018
Environmental Knowledge	3	7	6	1.02	43.00	2017
Municipal Solid Waste	1	8	6	1.02	8.00	2016
Remanufacturing	6	2	6	1.02	13.33	2019
Sustainable Development	6	6	6	1.02	11.33	2018
Waste	2	5	6	1.02	25.50	2019

These keywords collectively represent the main research areas and topics related to student awareness of SWM in HEIs. Analyzing the co-occurrence of these keywords helps identify recurring themes in research articles, revealing relationships and patterns between keywords. This analysis provides insights into common topics and concepts, facilitating a systematic exploration of connections and advancing our understanding of the state of the field [74].

The network analysis conducted in this study revealed six distinct clusters, as depicted in Figure 8. Cluster 1 (red) relates to "environmental waste management and pro-environmental behavior". Cluster 2 (green) focuses on "e-waste and recycling behavior,

emphasizing awareness and the theory of planned behavior". Cluster 3 (blue) centers on "enhancing environmental knowledge to drive conscious choices and actions". Cluster 4 (yellow) emphasizes "environmental education, SWM, recycling behavior, and their impact on attitudes". Cluster 5 (purple) explores "sustainability among university students, including attitudes, pollution concerns, and the attitude-behavior relationship". Lastly, Cluster 6 (light blue) highlights "waste management's role in promoting sustainable development".

Out of these clusters, cluster 1 includes a variety of keywords, including "recycling", "environmental attitudes", "food waste", "pro-environmental behavior", "waste sorting", "environmental behavior", "environmental concern", and "municipal solid waste". This cluster focuses on environmental waste management and pro-environmental behavior. The research in this cluster aims to explore effective strategies for waste reduction, promote recycling behavior, and address environmental concerns related to municipal solid waste. This cluster can aid in the creation of environmentally friendly waste management practices and increase awareness of the significance of pro-environmental behavior. Future emphasis should be placed on investigating interventions and policies that encourage waste reduction, enhance recycling behavior, and foster a broader environmental consciousness among individuals and communities [6,75,76].

In cluster 2, keywords such as "e-waste", "awareness", "recycling behavior", "theory of planned behavior", "electronic waste", "waste recycling", "college students", and "waste" are interconnected. It can be inferred that cluster 2 focuses on e-waste and recycling behavior, emphasizing awareness of SWM in HEIs. The presence of keywords such as "college students", "awareness", and "waste" suggests that this cluster explores e-waste management and recycling behavior among college students. The research in this cluster aims to investigate and understand how awareness can influence recycling behavior and e-waste management practices among college students. The findings of this research can be valuable in improving waste management practices in universities, promoting student awareness, and fostering a culture of environmental responsibility among students. Based on these inferences, it is suggested that future efforts should concentrate on developing targeted interventions and educational programs to enhance recycling behavior and e-waste management among college students. Additionally, there should be a focus on promoting student orientation towards sustainable practices, aiming to enhance their understanding and engagement in environmental conservation. By addressing these areas, colleges may contribute to broader environmental sustainability goals, promote sustainable practices, and foster a culture of environmental responsibility among students.

In cluster 3, keywords such as "environmental awareness", "sustainable consumption", "waste separation", "pro-environmental behavior", "theory of planned behavior", and "environmental knowledge" are interconnected. This cluster focuses on enhancing environmental knowledge to drive conscious choices and actions. The research in this cluster aims to study the factors influencing pro-environmental behavior and sustainable consumption patterns. This research can contribute to enhancing environmental initiatives in universities and improving student awareness of the importance of sustainability. In the future, there should be a focus on enhancing collaboration between universities and students in designing and implementing sustainability initiatives and encouraging active student participation. This will further promote sustainable practices and foster a culture of environmental responsibility among students.

Cluster 4 is centered around environmental education, SWM, recycling behavior, and their impact on attitudes in HEIs. The keywords "environmental attitudes", "environmental education", "attitudes", "knowledge", "recycling behavior", and "solid waste management" indicate that this cluster aims to investigate the relationship between recycling behavior, knowledge, attitudes, and environmental education in the context of SWM in HEIs. The research within this cluster focuses on understanding the factors influencing attitudes and behaviors towards solid waste management and exploring the effectiveness of environmental education programs. By studying this topic, researchers aim to enhance waste management and promote sustainable behaviors in HEIs. The findings of this re-

search can inform the development of effective educational interventions and policies to enhance environmental attitudes and behaviors in the context of solid waste management in HEIs.

Cluster 5 is centered around sustainability among university students, including attitudes, pollution concerns, and the attitude-behavior relationship. The keywords "sustainability", "university students", "environment", "attitudes", "pollution", and "behavior" indicate that this cluster aims to examine the attitudes of university students towards sustainability, their concerns about pollution, and the relationship between attitudes and behavior regarding sustainable practices. The research within this cluster focuses on understanding the factors influencing sustainability attitudes and behaviors among university students and exploring ways to promote sustainable practices on campus. The findings of this research can inform initiatives and interventions aimed at fostering a culture of sustainability among university students and promoting environmentally responsible behaviors.

Finally, cluster 6 focuses on waste management, specifically remanufacturing, and its connection to sustainable development. The research within this cluster aims to explore strategies and practices related to optimizing waste management processes through remanufacturing. By enhancing resource efficiency, minimizing environmental impact, and reducing waste, academics want to contribute to the aims of sustainable development. The findings of this study can help design sustainable strategies for resource conservation and waste reduction, as well as improve waste management practices.

4. Conclusions

The primary objective of this paper was to conduct a bibliometric analysis of articles pertaining to student awareness of SWM in HEIs. In order to achieve this aim, a total of 634 papers were chosen from the Scopus database and subjected to analysis utilizing VOSviewer software. The findings of this study have unveiled significant advancements in the field of research on student awareness of SWM in HEIs. More than 46.53% of the research publications on this topic have been published in the last five years, which suggests that interest in and attention to SWM has recently increased. The results also indicated a notable increase in research papers on student awareness of SWM in HEIs since 2013, which reflects a growing recognition of the importance of SWM. Based on the analysis of Scopus data, the most influential journals in the field of student awareness of SWM were identified as *Sustainability* (Switzerland) and the *Journal of Cleaner Production*. In terms of subject areas, the majority of research in this field was conducted within the realms of environmental science, social sciences, and engineering, representing 27.8%, 14.9%, and 9.96% of the research output, respectively. Among the countries contributing significantly to the research, China, the United States, the United Kingdom, Malaysia, and Spain emerged as the prominent contributors, accounting for 18.14%, 12.93%, 6.94%, 5.64%, and 5.52% of the research output, respectively. Notably, the Chinese Academy of Sciences and Tsinghua University emerged as the leading institutions in this research field. Furthermore, co-occurrence and clustering analyses were performed on the keywords present in the research papers on student awareness of SWM in HEIs. This analysis helped identify new and important research trends and issues. The keywords "recycling", "environmental awareness", and "waste management" were found to be the most frequently used, indicating the primary focus of the research in this field accurately. These keywords shed light on the core aspects being explored in the study of student awareness of SWM in HEIs. Overall, this study provides valuable quantitative insights into the growth and trends of SWM research within HEIs globally, offering a foundation for further scholarly inquiry and practical interventions aimed at enhancing SWM practices and environmental stewardship among students and wider communities.

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