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Global Characteristics and Trend Research of Green Competencies: A Review from Bibliometrics Analysis

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ABSTRACT

Research Aims: The increasingly pressing issue of global sustainability has increased the need for mastery of green competencies as critical competencies in the fields of education, organization, and environmental governance. However, until now, there are still limitations in systematic studies that analyze the trends and characteristics of global research related to green competencies. This study aims to identify international research trends, key actors, dominant terminology, patterns of collaboration between institutions and across countries, and recent developments in the study of green competencies by applying bibliometric analysis.
Methodology: This study employs bibliometric analysis, utilizing a dataset comprising 346 Scopus-indexed articles published between 2014 and 2024. The data were processed using VOSviewer and Biblioshiny software integrated with R Studio to generate visualizations, including co-authorship, co-citation, bibliographic coupling, and overlay network analyses.
Research Findings: The findings show that publications on green competencies have increased significantly since 2015, with Sustainability Switzerland, Journal of Cleaner Production, and Business Strategy and The Environment being the most productive journals (Figure 2). Dominant keywords include "sustainability development" and "green competencies" (Table 2, Figure 3). Countries such as China and the United States dominate publication contributions (Figure 4, Table 3), while institutions in several Malaysian countries are the centers of research productivity (Table 4). Networks of co-citation and bibliographic coupling show limited global collaboration across institutions (Figure 8).
Research limitations and implications: This research makes a significant contribution to mapping the epistemic landscape of green competencies and encourages the development of collaborative approaches across sectors. The findings are helpful for policymakers, academics, and educational practitioners in designing strategies to strengthen green competencies across various sectors.

Keywords: *Green Competencies, Sustainability Education, Bibliometric Analysis, Global Trends, VOSviewer, SDGs.*

INTRODUCTION

Many countries around the world are struggling to achieve the Sustainable Development Goals (Pandey et al., 2025). However, the data, according to the Sustainable Development Report (2024), revealed that only 16% of the SDGs targets will be achieved globally by 2030. Meanwhile, the remaining 84% showed limited progress or reversed. In general, achieving sustainable development requires considering the complexity of the socio-ecological system, which encompasses economic, ecological, social, and political factors (Mahanayak, 2024). However, the road to sustainable development is fraught with many challenges and obstacles. Studies by D'Sa et al. (2018), point out that the weak technical and non-technical skills required in the labor market are one of the main factors. In addition, research conducted by Halkos & Gkampoura (2021) found that in some countries in Sub-Saharan Africa, Latin America, the Caribbean, and the Pacific Islands, there are no full-time jobs and an inadequate number of productive workers. Finally, data from the International Labour Organization (2018) show that only about 60% of new workers possess the necessary skills or environmental certifications for Green Jobs positions.

This condition highlights the importance of green human resource management (Green HRM) in providing training focused on environmental sustainability (Tari & Nirmala, 2023). One of the vital competencies to encourage sustainable growth and improve company performance is green competencies (Nurcholis et al., 2024). Green competencies comprise six main components that complement each other, namely green knowledge, green ability, green skills, green attitude, green behavior, and green awareness, enabling employees to support complex organizational sustainability initiatives (Ozilhan et al., 2024). This approach can help companies ensure that employees can identify, develop, and implement green business practices, thereby enhancing a culture of sustainability (Mirčetić et al., 2022). Thus, the implementation of green HRM, which focuses on actualizing the dimensions of green competence, is an important strategy for improving sustainability culture, supporting environmentally friendly business initiatives, and encouraging sustainable company growth.

Green competencies have garnered significant attention from practitioners because they are driven by an awareness of the importance of green competencies for the sustainability of a dynamic business environment (Ayush, 2024). Sustainability skills are an important key to the success and survival of a company. In business practice, specific sectors have begun to emphasize green competencies as a key pillar in the hiring and development process of employees. Studies by Nurcholis et al. (2024) indicate that the shipping industry is beginning to prioritize green competencies, aiming to impart knowledge, skills, attitudes, and awareness of environmental friendliness to support sustainable shipping management. In addition, a study by Ali et al. (2022) situates the conceptual framework of Green HRM as a direct representation of green capabilities within the context of Islamic banking. This paves the way for green jobs and a sustainable labor market (Kozar & Sulich, 2023). Therefore, improving green competencies across sectors can help regulatory compliance and competitiveness and accelerate the achievement of the Sustainable Development Goals (SDGs).

Studies by Cabral & Dhar (2021) have emphasized the conceptual formulation and dimensions of green competencies, but their study has not examined the evolution of keywords, geographic distribution, and author collaboration. Similarly, studies by Yafi et al. (2021) focus on the dimensions of green competency and motivation as mediating factors in

the relationship between green training and environmental performance. Meanwhile, a study by Hong et al. (2024) focuses on training and motivation that encourage pro-environmental action in the workplace but does not map out a citation network. Therefore, to close the empirical gap and address the lack of research, these researchers conducted bibliometric analyses to explore research trends, map future novelties, and build a comprehensive literature on green competencies. The study is designed to answer two key research questions such as: what are the global characteristics of green competency-related research, including geographical distribution, institutions, author contributions, dominant keywords, and the most influential literature in this concept?; What is the direction and evolution of green competency research trends over time, as well as what research gaps can be used as a foothold for the development of future research agendas in supporting the transition to sustainability?

The research aims to find emerging areas of research, find potential collaborators, and find suitable sources for publication. This is because many disciplines often ignore green competence when building literature (Cabral & Dhar, 2021). Furthermore, this study also aims to strengthen the literature related to the role of green human resource management by increasing understanding, development, application, and impact of green competency in the organizational environment through a systematic literature review (Ullah et al., 2024). This study can serve as a practical investigative tool that examines how green competencies can help companies develop sustainable industries, including in the context of Islamic banking. Using a bibliometric approach, this study aims to measure patterns, directions, impacts, and collaborative networks in publications that discuss green competencies more comprehensively, thus providing a framework for future research development.

LITERATURE REVIEW

Sustainable Development Goals

The United Nations adopted the Sustainable Development Goals (SDGs) as a Global Goal in 2015, marking a collective effort to end poverty, protect the Earth, and ensure that by 2030, everyone will live in peace and prosperity (Omotosho et al., 2023). Along with other international agreements, such as the Paris Climate Agreement and the Aichi Biodiversity Target (Couce et al., 2023; de Castro-Pardo et al., 2022), sustainable development by 2030 aims to ensure that development patterns lead to well-being and social inclusion while maintaining stable systems that support the Earth's biophysical life. There are 193 countries committed to a common development agenda aimed at achieving economic prosperity, social improvement, environmental restoration, and better governance (Sachs et al., 2024). Previous research by Abidi & Jamil (2023) demonstrates that sustainable development is an important goal intrinsically linked to the survival of individuals, communities, environments, countries, nations, and the world. The value gained also provides a crucial aspect for human capital investment and economies worldwide (Singhal et al., 2023). Awareness of sustainable development must be supported by the capabilities of human resources, including health and education, as well as intellectual capital (technology and scientific knowledge), and natural capital (Şentürk et al., 2023).

The Sustainable Development Framework consists of 17 goals, all of which must be achieved by 2030. According to data from the United Nations Department of Economic and Social Affairs (2023), There are 17 goals in sustainable development such as (1) No poverty,

(2) No hunger, (3) Good health and well-being, (4) Quality education; (5) Gender equality; (6) Clean water and sanitation; (7) Affordable and clean energy; (8) Decent work and economic growth; (9) Industry, innovation and infrastructure; (10) Reduced gaps; (11) Sustainable cities and communities; (12) Responsible consumption and production; (13) Climate action; (14) Life underwater; (15) Life on land; (16) Peace, justice and strong institutions; and (17) Partnerships for these purposes. Based on these goals, a holistic and integrated approach is necessary because sustainability goals are interdependent and mutually influence one another. This understanding applies in both developed and developing countries. Therefore, awareness of the importance of sustainability presents a challenge, and a shared response based on data and evidence is necessary to monitor progress and adjust regulations in implementing programs following the needs of sustainable development (Fleaca et al., 2023).

Green Competencies

Studies by Steele (1980) define green competence as the ability of people to interact with their surroundings constructively and reflect exceptional enthusiasm. In literature management, green competencies encompass (1) outdoor practice skills, resource conservation, and awareness; (2) awareness as part of an individual's attitudes, styles, and values; and (3) knowledge, including how to seek and acquire environmental information (Pedersen, 1999). Meanwhile, a study by Cabral & Dhar (2021) explains that green competence is a hierarchical disposition structure comprising green knowledge, green skills, green awareness, green attitudes, green abilities, and green behaviors, developed based on a thorough literature review. In summary, a person's capacity to interact with the environment constructively and enthusiastically is demonstrated by dimensional structures such as green knowledge, green skills, green awareness, green attitudes, green abilities, and green behaviors. To achieve this sustainability mission, green awareness is necessary, encompassing environmental, social, cultural, and economic aspects that are interrelated and influenced by individual beliefs, perspectives, and behaviors (Yandamuri, 2022). The implementation of green competencies ensures that economic growth does not come at the expense of the environment or the peace of workers (Hendratmoko, 2023).

The green competency approach not only enhances the perspective on sustainability but also provides a practical foundation for green human resource management. In training and development programs featuring project-based modules and system simulations, green competencies can enhance employee behavior and retention, ultimately improving green performance through the development of skills, abilities, knowledge, attitudes, and awareness (Cabral & Dhar, 2019; Yafi et al., 2021). Meanwhile, in performance management, the determination of performance assessment metrics that include SDG indicators (such as energy efficiency and emission reduction) is used to align pro-environmental goals and provide extrinsic rewards to workers who achieve these goals (Ahmad et al., 2023; Nguyen et al., 2025). Meanwhile, the implementation of green job design is carried out by integrating eco-friendly skills in implicit job positions with a focus on eco-friendly skills and abilities, such as including waste management and green supply chain responsibilities into the to-do list so that employees' operational responsibilities are in line with sustainability goals (Uche & Moyosore, 2025). In line with this statement, there is a need for green practice initiatives through green empowerment programs that involve employees in environmental management decision-making (Nguyen et al., 2025 ; Roscoe et al., 2019).

Bibliometrics Analysis

Bibliometric analysis is a method that helps build theories empirically by collecting and analyzing knowledge (Salinas-Ríos & García López, 2022). In other words, a set of indicators is studied from a set of documents, and the results will be evidence that there are elements of science that need to be explained in order for the conclusions to be made to have a higher level of scientific transcendence (Duschl et al., 2021; Olesk et al., 2021). This study also enables the determination of the quality and quantity of scientific production and its impact on the social level. There are three main functions of bibliometrics, namely the description function, the evaluation function, and the monitoring function of research activities (Herrera Horta & Gutiérrez García, 2023).

In addition, the descriptive-type bibliometric study mode provides a comparative analysis of scientific productivity based on quantitative information about articles published at the country, provincial, city, institutional, and even individual levels (Konu & Ozay Kose, 2024; Şahin & Bil, 2024). It enables the identification of the most productive researchers and institutions, understanding the scientific production on a particular topic, and describing the profile of the publications created, including the type of study, publication, and study population. With the right approach, bibliometric analysis can be a highly effective tool for understanding the research landscape and informing future strategies in various scientific areas (Solis Pino et al., 2024).

RESEARCH METHOD

This study uses bibliometric analysis to investigate the topic of Green Competence descriptively. In this study, we analyzed data collected from a Scopus database from 2014 to 2024. Scopus was chosen as a suitable source for this study because of its comprehensive coverage and reliable citation indexing. The bibliometric method is employed to assess contributions at various levels and visualize the concepts and intellectual structures of knowledge and collaboration within a specific area of knowledge (Liao et al., 2024). The data was analyzed from various perspectives using VosViewer and Biblioshiny. The process of identifying data sources involves entering keywords on the Scopus platform. The researcher establishes appropriate inclusion and exclusion criteria in searching for keywords, titles, and abstracts in the database. To ensure our results are qualified, the keywords used in the document search are green competencies. Data lookup is provided with a query TITLE-ABS-KEY (green AND competencies) AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar")).

The following process is data filtering. The data filtering process is carried out with various limitations such as document types limited to articles (exclude: erratum, notes, short surveys, editorials, book chapters, review papers, conference papers), publication stage limited to final publication (exclude: article in press), source type limited to journals (exclude: Trade Journal, Book Series), and language limited to English (exclude: French, Azerbaijani, Italian, Polish, German, Chinese, Russian, Spanish). The data filtering process resulted in 346 publications that matched the keyword. Furthermore, the manual validation process involves reconciling the title and abstract from the journal. The validation process involves selecting components that align with the concept and elements of green competence outlined in the publication article. All data were then analyzed using VOSviewer

and Biblioshiny with parameters such as co-occurrenceence analysis with a threshold of 3-5 times. In addition, co-citation should only be performed on documents that have more than ten citations and a minimum of two linkage strengths. Then, the bibliography coupling is selected from the connection of two documents that have at least three shared references. Thus, the visualization of this co-authorship, co-citation, and co-occurrence network can reveal contribution patterns, intellectual clusters, and development trends in green competencies topics.

SPAR-4-SLR Protocol

Research conducted by Paul et al. (2021) developed a methodological framework based on Scientific Procedures and Basis of Thought for Systematic Literature Review (SPAR-4-SLR), which was then adopted in this bibliometric study to analyze the concept of green competence. These protocols enable researchers to anticipate potential problems, reduce ambiguity, enhance accountability, and maintain research integrity (Kim, 2022). The development of protocols is an important component of a systematic literature review. The development of protocols ensures careful planning, consistency in implementation, and transparency, allowing for replication (Al Shakarchi, 2022). Figure 1 illustrates the approach for each protocol level, which involves assembling, arranging, and assessing.

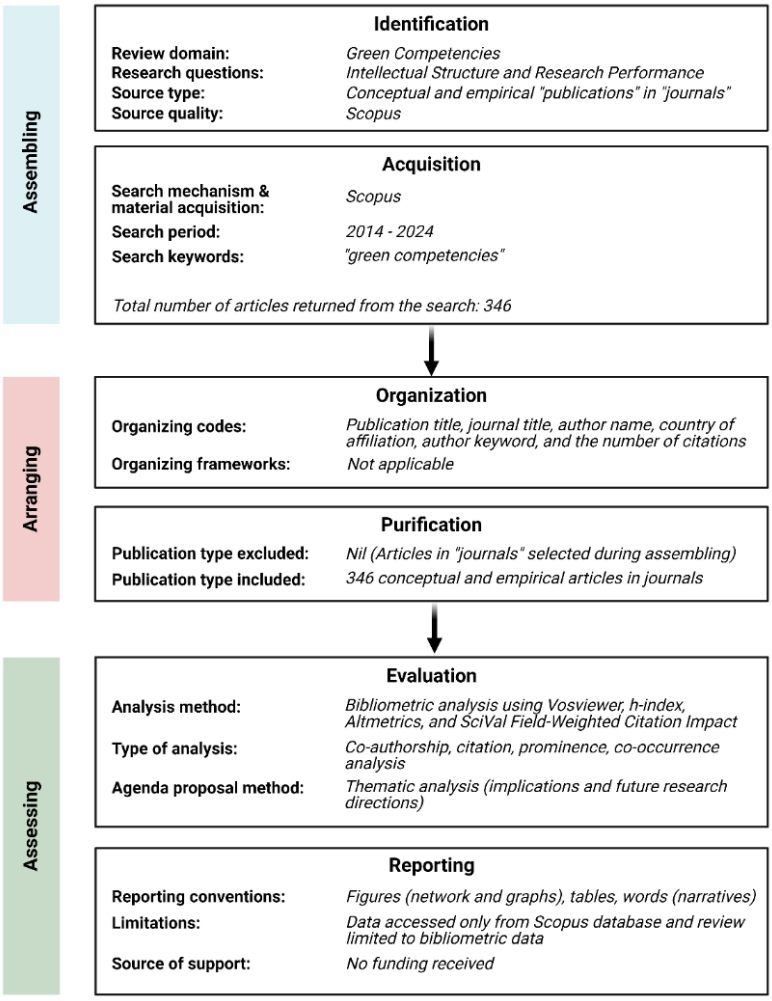

Figure 1. Research design using SPAR-4-SLR protocol (Created with biorender.com , 2024, License Code: QV272ZHI9B)

Assembling

The first stage is assembly, which involves the process of searching and obtaining publications for review. The search process was conducted using the keywords "green competencies" on July 24, 2024, across abstracts, titles, and keywords. The results of the study show that between 2014 and 2024, 346 publications were obtained.

Arrangement

The next stage is organizing. Publications are organized and refined through a process of inclusion and exclusion. Journal title, publication title, author name, keywords, affiliate country, funding organization, total citations, total publications, FWCI, and altmetrics attention score are used to organize publication search data. No publications were rejected in the purification of this study.

Assessing

The last stage is the assessment. This stage includes the evaluation and reporting process. The evaluation section of this article discusses the analysis techniques and limitations of the research. The main tools used for trend evaluation and analysis are Vosviewer and Biblioshiny. Furthermore, the researcher provided information that ethical clearance was not required because the strategic review was based on secondary data from Scopus, which is general (accessible to anyone).

RESULTS AND DISCUSSIONS

This study presents a systematic mapping of the global literature on green competencies, including an analysis of publication trends, contributions from countries and institutions, as well as intellectual networks between researchers and key themes. The findings of the bibliometric analysis indicate that the study of green competencies has experienced rapid growth over the last two decades, particularly in the areas of sustainability, education, and human resource capacity development across various industrial and government sectors. This phenomenon aligns with global demands for sustainable development, environmental regulations, and industrial transition toward a greener economy that is more ecologically minded (Shao et al., 2024). The statement suggests that green competencies are no longer merely part of an alternative academic discourse but have become mainstream in the debate about global sustainability (Valle et al., 2024). The topic of "green competencies" has garnered significant attention in the academic literature as awareness of sustainability issues has increased worldwide. As stated by Valle et al. (2024), one of the important factors for the success and sustainability of a company is the implementation of green competencies in the company culture. Where these competencies can improve the quality of the organizational environment, this indicator shows the importance of the topic of green competence, as demonstrated by the growing number of publications and citations related to the topic.

Publication and citation trends

The results of this study demonstrate that searching for the keyword "green competencies" in the Scopus database yielded 346 articles, comprising both empirical and conceptual publications, spanning the years 2014-2024. Table 1 illustrates a significant increase in the number of published articles over the past decade. Additionally, the total number of citations reached a remarkable 5,985 during the same period.

Table 1. Publications and citation trends

Year	Number of Papers	Number of Citations
2014	15	84
2015	9	399
2016	13	581
2017	14	1.331
2018	19	734
2019	33	964
2020	35	588
2021	46	180
2022	51	692
2023	65	107
2024	46	325
Total	**346**	**5.985**

Source: Scopus Database

The data shows the popularity of the topic of "green competencies" among academics. The trend of publications and citations on "green competencies" shows significant dynamics in the academic literature. Table 1 shows that the most significant increase in publications over the last 10 years occurred in 2023, with a total of 65 documents published that year. This indicates the growing enthusiasm for research amid pressure to achieve the Sustainable Development Goals (SDGs) worldwide. Meanwhile, the highest number of citations occurred in 2017, with a total of 1,331 citations. The increase in the number of publications and citations occurred due to the growing prevalence of Sustainable Development Goals (SDGs) campaigns in various countries, particularly in efforts to reduce carbon emissions. Additionally, this phenomenon suggests the presence of a phase of intellectual consolidation. In this phase, important works become the primary reference for building a new paradigm on green competencies in organizational management, education, and human resources (de Haan, 2010; Wiek et al., 2011).

Documents per year by sources

The study's results indicate that 10 journals are relevant to the field of green competence. Figure 2 compares publication trends from each of the different journal sources. 2 axis indicators support the results of the source comparison. The X-axis represents the performance of documents measured from 2014 to 2024. Meanwhile, the Y-axis represents document performance, measured by the number of documents per year. The graph illustrates an increase in the number of documents published annually in several journals since 2020. This indicates that green competence and sustainability are gaining increasing attention. Figure 2 below can help identify the most active and productive sources of green competence.

Figure 2 provides an overview of publication trends over the past decade. Overall, it is evident that the trend of publications has begun to increase since 2020. This is due to the world's increased attention to the Sustainable Development Goals (SDGs), especially as they relate to the circular economy, reducing carbon emissions, and transforming the green workforce. In 2020, the Swiss Journal of Sustainability experienced a significant upward trend. This increase peaked in 2023. This indicates that the journal addresses sustainability issues across various sectors, including the development of green competencies in industry, education, and public policy. Thus, this journal can serve as a primary source of reference for academics and practitioners seeking to investigate green competencies in a

comprehensive and multidisciplinary manner, particularly concerning environmental sustainability. In addition, the Journal of Cleaner Production and Business Strategy, as well as The Environment, have consistently published several articles since 2020, with a slight decline in submissions in 2023.

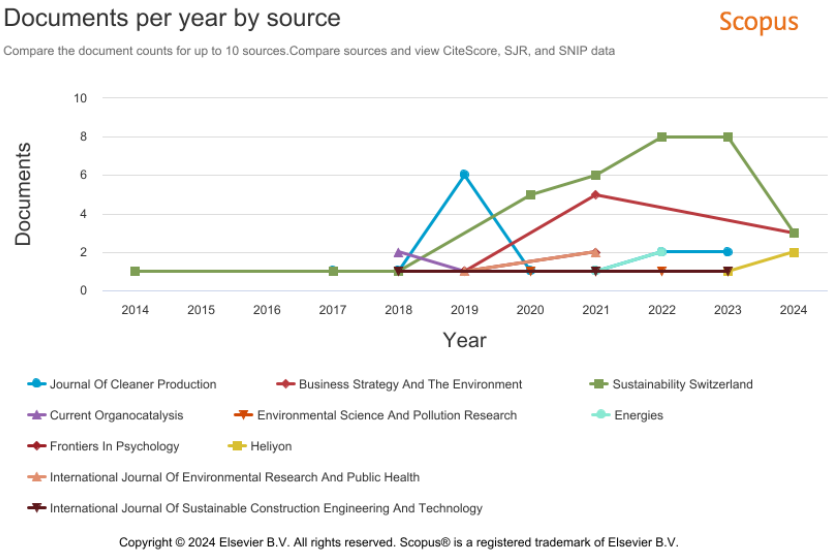

Figure 2. Top 10 Research Publication Sources
Source: Scopus Database

These journals may serve as a valuable reference for supporting green competencies in future research. In contrast, the journals Current Organocatalysis and Frontiers in Psychology have made little contribution to increasing the quantity of documents. This decline occurred because these journals had less relevant topics compared to other journals. The ranking of these top 10 journals can be beneficial for researchers and practitioners to stay informed about the latest advances in sustainable, green, eco-friendly competencies. Thus, the analysis of publications from journal sources reveals that research on green competency has increased quantitatively, and this topic has become a top priority on the world's academic agenda. To enhance the academic impact and practical benefits of green competency research, future publication strategies, and scientific collaborations should consider these key channels for dissemination.

Word cloud of titles using the Biblioshiny

Table 2 shows the distribution of the most significant words and the frequency with which they are used. By identifying the most frequently used keywords, this table serves as a tool for readers to quickly understand the text's emphasis on sustainability, environmental issues, and education. In general, academics conduct multidisciplinary research to advance this paradigm, resulting in a robust set of theories and conceptual models that reinforce its fundamental principles.

As illustrated in Table 2, prominent thematic priorities in this domain include sustainable development, green competence, and environmental performance. "Sustainable development" has many uses (19 times). However, the high frequency of "green competencies" suggests that individuals and organizations must improve their ability to address environmental issues through strategic and innovative approaches (Cabral & Dhar, 2021). Green competencies have emerged as an important focal point as organizations

become increasingly aware of their role in driving competitive advantage. Previous studies by Cabral & Dhar (2021) argue that these competencies enable companies to leverage internal capabilities to achieve ecological efficiency, going beyond reactive compliance to external market pressures. Companies that develop strong green competencies not only improve energy efficiency and reduce their carbon footprint but also position themselves to navigate the ever-evolving regulatory landscape, thereby securing long-term profitability and operational resilience.

Table 1. Top 10 keywords used in the author's keywords

Words	Occurrences
Sustainable Development	19
Green competencies	18
Competencies	11
Environmental Performance	10
Higher Education	9
Green Economy	8
Education	6
Environmental sustainability	6
Green Chemistry	6
Green Supply Chain Management	6

Source: Scopus Database

More detailed green competencies are presented through the word cloud in Figure 3. A word cloud is a visual representation that describes the frequency of words from textual data, where the size of each word corresponds to its prevalence or relative significance in the corpus being analyzed (Atenstaedt, 2017). Word clouds offer an overview of keywords related to green competencies, with larger words showing greater significance compared to smaller words.

Figure 3. Top 10 Word Cloud of Tittles
Source: Data processing using Biblioshiny

Based on the findings from Figure 3, the researchers revealed that the keyword "sustainable development" was the most frequently used term, followed by "green competence," which was consistently used in the study. Figure 3 shows that the coverage of

the keyword "green competence" is lower when compared to "sustainable development" in the 2014-2024 timeframe. In addition, the emergence of terms such as "environmental performance," "higher education," and "green economy" suggests that green skills research is not only technical but also closely related to management, institutional, and educational issues.

For example, the human resource management division could use these findings as a basis for developing a more measurable and focused green HRM policy based on the occurrence of keywords. To ensure that employees acquire applicative skills and a pro-environmental attitude, environmental training modules can be structured based on the most frequently emerging cluster of topics. This approach will enable each worker to be evaluated based on their contribution to the SDG targets and economic productivity. This will support the development of new KPI metrics in the annual evaluation. Thus, this analysis not only sheds light on the conceptual structure of green competency research but also facilitates further mapping of the relationships between topics in practice. This can help build a contextual sustainable competency model that can be applied.

Document by Country

Scientific publications that discuss green competence have varying levels of popularity in different countries. This is illustrated in Figure 4, which shows the production of scientific papers across various countries. This map illustrates the prevalence of green competency research in various countries, which is then analyzed to identify its key characteristics. This map uses blue with varying degrees of darkness. The darker the blue color, the more scientific production there is in the country. Figure 4 below shows the distribution of scientific publication production in different countries.

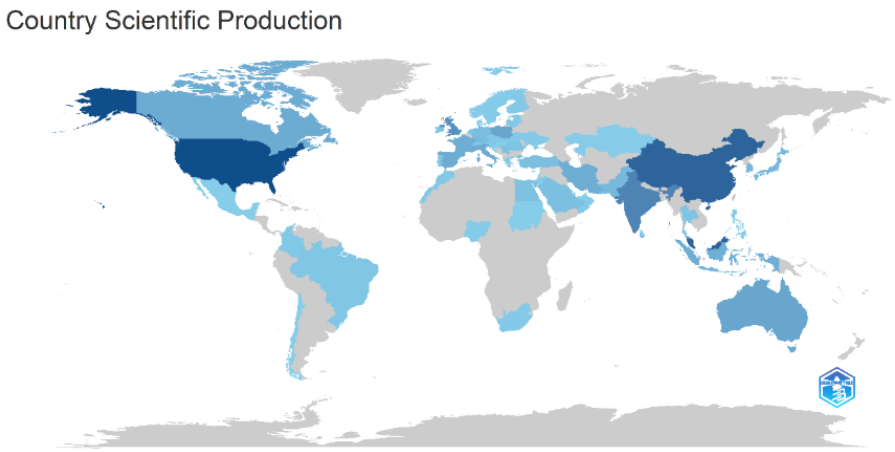

Figure 4. Country Scientific Production
Source: Data processing using Biblioshiny

Countries such as the United States, China, the United Kingdom, India, and Malaysia make significant contributions to the scientific production of green competencies, as evident from the bibliometric analysis presented in Figure 4. The results of the publication distribution in Table 3 show that the United States and the United Kingdom dominate in terms of citations (1,206 citations), while Malaysia recorded the highest number of documents (47 documents). This demonstrates its productivity and global influence in the field of research. Additionally, Australia has the highest number of citations per publication,

with an average of 33.65 citations per article. According to the information gathered, publications from several countries have had a significant impact and contributed substantially to the advancement of scientific research. In addition, the cooperation network between countries such as China and the UK occupies the highest position in terms of full link strength, with a total link strength value of 34. This indicates that the two countries are collaborating effectively in relevant publications. In this regard, Pakistan also maintains a cooperative relationship, with a total value of 32 links, despite fewer documents and citations.

Table 3. Publications and citation trends

Country	Documents	Quotes	Citations per publication	Total link strength
China	43	945	21,98	34
United Kingdom	35	1026	29,31	34
Pakistan	15	121	8,07	32
India	33	482	14,61	28
Poland	17	231	13,59	24
Malaysia	47	623	13,26	22
United States	45	1206	26,80	13
Canada	13	177	13,62	12
Indonesia	15	95	6,33	11
Australia	20	673	33,65	10

Source: Scopus Database

As a first step in understanding how green competency research correlates with the implementation of the SDGs at the global level, an analysis of the distribution of publications by country reveals that Malaysia leads the list with 47 documents. According to the SDGs report index (2024), Malaysia ranks 79th out of 166 countries, with a score of 69.32. The position reflects a significant push from Malaysian academics and practitioners to develop green competencies in response to national needs, including the launch of the SDGs Roadmap and the green HRM professional certification program (Sachs et al., 2024). It was followed by the United States, ranking 46th with an index score of 74.43, which was marked by many companies integrating environmental KPIs (SDGs 7 and 13) into their employee performance assessments (Sachs et al., 2024).

In addition, a report from the Sustainable Development Report (2024) indicates that China is leveraging this increase in publications to support green training reforms in the manufacturing industry, in line with the Five-Year Plan that emphasizes resource efficiency with a rating of 68 and a score of 70.85. Meanwhile, the UK, which holds the top position for the SDGs with a rank of 9 and an index score of 82.16, demonstrates a focus on research on green capabilities and more advanced green human resource management practices, such as established carbon incentive programs and sustainable training modules (Sachs et al., 2024). Thus, the achievement of the high SDGs is closely related to the dominance of green competency publications, as evidenced by the implementation of green HRM through global roadmaps, environmental key performance indicators (KPIs), and sustainable training.

In general, researchers need a bibliometric map of relations between countries to identify patterns of country document networks that are cited together by other countries' documents. The network aims to help find the intellectual foundations of a particular field of

study, such as getting an in-depth picture, finding knowledge gaps, obtaining new information for research, and knowing the country's contribution to various fields (Dulla et al., 2021; K, Kadirhanogullari & E, Kose, 2024). The visualization of collaboration networks between countries refers to scientific publications on green competencies shown in Figure 5 below.

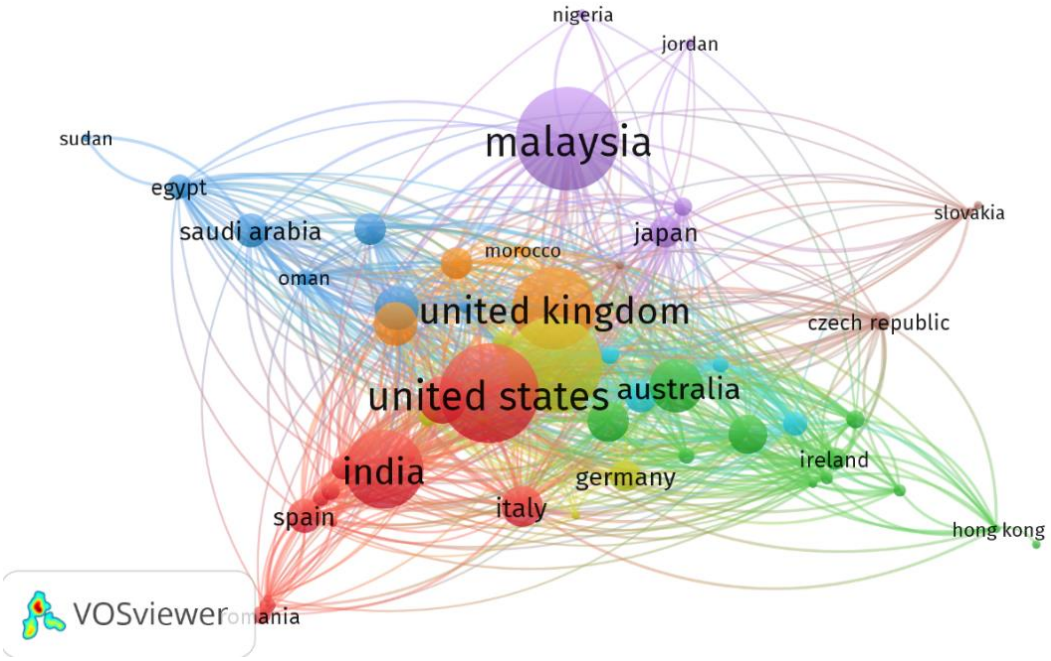

Figure 5. Bibliographic Coupling Countries
Source: Data processing using VOSviewer

The visualization in Figure 5 produces outputs in the form of international thematic focus, academic collaboration, and the intensity of author involvement in the research. Visualizations of international collaboration networks generated through VOSviewer analysis reveal an intense pattern of co-authorship among the leading countries in the study. The results of the bibliometric mapping reveal a global collaboration network structure dominated by three core countries: the United Kingdom, India, and the United States, which occupy a central position, as reflected in the size of their nodes. This shows that these countries have made a significant contribution to research on the topic of green competence. Additionally, each node contains several different color clusters. This color cluster highlights a group of countries with high bibliographic ties, with Red focusing on India, Spain, Romania, Italy, and the United States. Australia, Ireland, Hong Kong, and Canada are in the green cluster. Sudan, Egypt, Saudi Arabia, Oman, Pakistan, and South Korea are in the blue cluster. China, Denmark, and Germany are in the yellow group. Nigeria, Jordan, Malaysia, and Japan are in the same group as the purple group. Austria, Brazil, France, and the Netherlands are in the light blue group. Indonesia

The Most Productive Universities and Institutions

This study classifies university affiliations that publish research within the scope of green competency studies. It was found that university affiliations conducting green competency research were mostly from universities located in Malaysia, China, and the United Kingdom. Based on the results of the bibliometric analysis, research on green

competency has not been carried out with high intensity. Table 4 presents the highest number of studies from various universities that have conducted research and published results over the last ten years.

Table 4. The most productive Universities and Institutions

University/Institute	Documents	Country
Tun Hussein Onn University Malaysia	6	Malaysia
MARA University of Technology	5	Malaysia
Universiti Teknologi Malaysia	5	Malaysia
Universiti Sains Malaysia	4	Malaysia
National University of Malaysia	4	Malaysia
Dongbei University of Finance and Economics	4	China
Cardiff University	4	United Kingdom
University of Malaya	4	Malaysia
Griffith University	4	Australia
Universiti Malaysia Perlis	4	Malaysia

Source: Scopus Database

The results of a bibliometric analysis of publications discussing green competencies over the past decade show that many institutions are productive in Asia, particularly in Malaysia, with six published scientific papers. In this regard, Universiti Tun Hussein Onn Malaysia (UTHM) occupies the top position, as shown in Table 4. In line with this statement, Universiti Tun Hussein Onn Malaysia also supports the sustainable development of learning methods, curriculum, and teaching techniques. Five other universities from Malaysia that made it into the top ten are Universiti Teknologi MARA, Universiti Teknologi Malaysia, Universiti Sains Malaysia, Universiti Kebangsaan Malaysia, and Universiti Malaya, showcasing Malaysia's dominance in this industry. One of the curriculums that continues to be developed by the academic community in Malaysia is Green-TVET Models (Amirul et al., 2024). Several academic communities in Malaysia also continue to develop green competencies among lecturers (Kowang et al., 2020). Research results from Hooi et al. (2012) show that the development of green university readiness in Malaysia has been quite significant since the beginning of 2012. This indicates the university's readiness to welcome the maturity of a green institution.

The findings are reinforced by a study from Hooi et al. (2012), which shows that since the beginning of 2010, the readiness of Malaysian universities to implement green university standards has increased. The active role of the academic community in these institutions shows that Malaysia's national higher education policy has included green competency development as a strategic component. Green competency studies are still developing around the world. However, some universities have demonstrated a commitment and consistency in developing more sustainable educational methods. The fact that Malaysia has numerous educational institutions indicates that the country is laying a strategic foundation for transforming its higher education system in a more environmentally friendly direction.

Bibliometric Analysis of the Keywords

The findings from the keyword analysis reveal the relationship between the various keywords, described as nodes, and the ends of the interconnected nodes. The size indicates the frequency and importance of the keyword. Furthermore, the difference in color composition indicates that the nodes belong to different topic groups. Then, the number of letters or keywords shows a frequency that is proportional to the rate of occurrence. Words

that have a position closer to the center of the network indicate a larger composition of the node. Figure 6 is a visualization of the keyword network, taken from a research article related to the scope of "green competence."

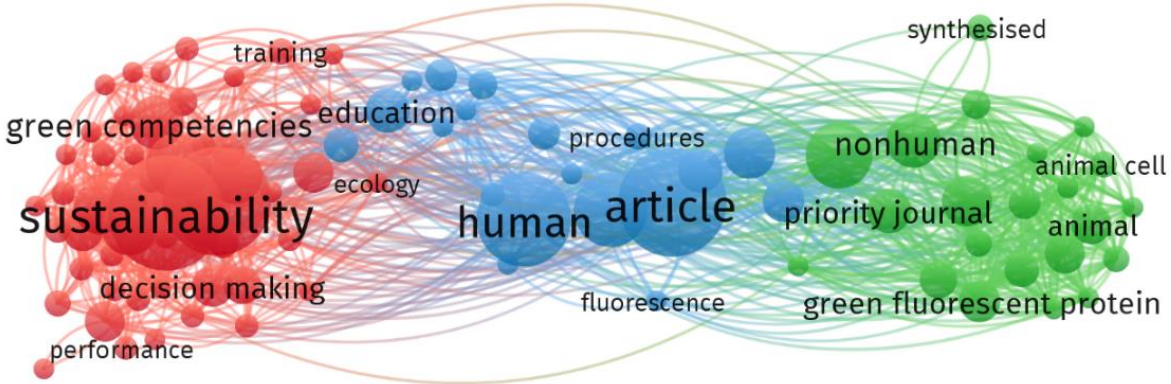

Figure 6. Distribution of the keywords
Source: Data processing using VOSviewer

The results of the analysis, as shown in Figure 6, indicate that the distribution of keywords is divided into three groups of keywords that appear simultaneously in the bibliography. The first red group highlighted several keywords, including sustainability, green competence, education, training, decision-making, ecology, and performance. This keyword highlights the importance of ecological training in enhancing performance and informing sustainable decisions. These findings can also be synthesized and used as a reference for green competency studies. This group demonstrates that green skills are crucial for achieving sustainability. This can be achieved through ecological training and education that will improve performance and support individuals or organizations in making decisions about sustainability.

Some keywords are mentioned in the blue group, such as "human," "article," "fluorescence," "procedure," and "education." The group demonstrates that the literature on green competencies is widely utilized to develop and enhance teaching techniques in fluorescence-focused chemistry. Finally, the literature from the green group describes its characteristics and applications in the field of applied chemistry, with a focus on non-human and animal cell research. Overall, the group discusses the development of individuals in studying chemistry to improve their abilities and reduce the biases and gaps found in the subject. Understanding the latest trend literature requires overlay visualization. Figure 7 is a research trend related to green competence

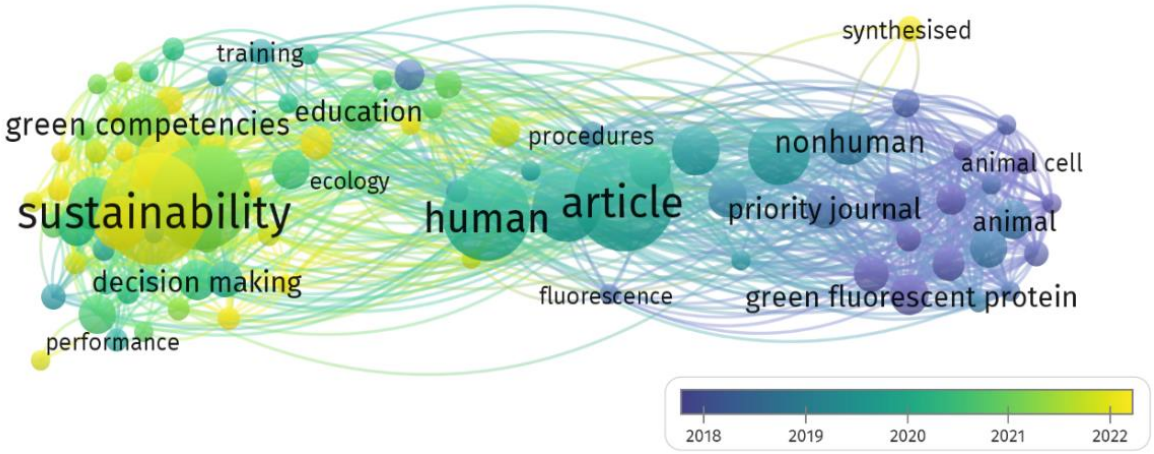

Figure 7. Overlay Vizualization
Source: Data processing using VOSviewer

As the overlay visualization above illustrates, a paradigm shift is evident in the literature on green competencies. At the beginning of the emergence of this topic in 2018-2019, knowledge trends centered on the field of applied chemistry, including green fluorescent proteins, synthetic analysis, animal cells, and non-human cells. Meanwhile, in 2020, a micro-shift occurred in the use of this topic in procedures employed in applied chemistry research and its application to human subjects, which had never been previously reported in the literature. Ahead of the 2021-2022 period, research on green competencies focuses on utilizing them as a tool to enhance performance and decision-making, as well as on how to integrate them into ecological education and training for organizations or individuals to achieve sustainability. These results demonstrate that research on green competencies has evolved from the field of technical science to one of practical applications, such as sustainability management and education.

The Most Cited Publication

Citations play a significant role in research (Agarwal et al., 2023; Liang & Lee, 2023). Essentially, the quality of the work and the scientific integrity depend on the use of citations. This demonstrates that the research conclusions are grounded in previous evidence, which provides a robust theoretical and methodological foundation (Seuring et al., 2021). In line with this statement, the researchers present the findings in Table 5, which relate to the ten most important papers referenced in the most cited publications. In addition, the general characteristics, based on the publication's findings, generally focus on the application of green competencies and the development of sustainable competencies. Research by Awan et al. (2021) suggests several implications for developing resource acquisition capabilities to enhance the innovation of green products, as well as in the context of Islamic banking (Pertiwi et al., 2024). This research supports the goal of developing green competencies to foster mindsets by helping users acquire the knowledge, skills, and attitudes necessary to think, plan, and act in a manner that demonstrates empathy, responsibility, and concern for the Earth (Bianchi et al., 2022).

Table 5. The most cited publications

Rank	Authors	Title	Cited by
1	Renwick, D. W. S., Jabbour, C. J. C., Muller-Camen, M., Redman, T., & Wilkinson, A. (2016)	Contemporary developments in Green (environmental) HRM scholarship	268
2	Awan, Usama & Arnold, Marlen & Golgeci, Ismail. (2021)	Enhancing green product and process innovation: Towards an integrative framework of knowledge acquisition and environmental investment	222
3	Pinzone, Marta & Guerci, Marco & Lettieri, Emanuele & Huisingh, Donald. (2019)	Effects of 'green' training on pro-environmental behaviors and job satisfaction: Evidence from the Italian healthcare sector	212
4	Ghobakhloo, Morteza & Iranmanesh, Mohammad & Grybauskas, Andrius & Vilkas, Mantas & Petraite, Monika. (2021).	Industry 4.0, innovation, and sustainable development: A systematic review and a roadmap to sustainable innovation	151
5	Quan, Xiaofeng & Ke, Yun & Qian, Yuting & Zhang, Yao. (2021)	CEO Foreign Experience and Green Innovation: Evidence from China	151
6	An, Hui & Razzaq, Asif & Nawaz, Ahsan & Noman, Sohail & Khan, Syed. (2021)	Nexus between green logistic operations and triple bottom line: evidence from infrastructure-led Chinese outward foreign direct investment in Belt and Road host countries	137
7	Maleki, Hajar & Whitmore, Lawrence & Hüsing, Nicola. (2018)	Novel Multifunctional Polymethylsilsesquioxane - Silk Fibroin Aerogel Hybrids for Environmental and Thermal Insulation Applications	134
8	Alsheyadi, Anwar & Muyldermans, Luc & Kauppi, Katri. (2019).	The complementarity of green supply chain management practices and the impact on environmental performance	125
9	Niu, Niumingxu & Zhang, Jasmine & Zhang, N & Uribe, Imelda & Tao, F & Han, Zhuoning & Pathak, Sen & Multani, Asha & Kuang, J & Yao, Jiaozhuoran & Bast, Robert & Sood, A & Hung, M-C & Liu, Jas. (2016)	Linking genomic reorganization to tumor initiation via the giant cell cycle	111
10	Muangmee, Chaiyawit & Dacko-Pikiewicz, Zdzisława & Meekaewkunchorn, Nusanee & Kassakorn, Nuttapon & Khalid, Bilal. (2021)	Green Entrepreneurial Orientation and Green Innovation in Small and Medium-Sized Enterprises (SMEs)	98

Source: Scopus Database

Table 5 shows that the most cited publications in studies on green competencies primarily focus on green innovation, the implementation of environmentally sound practices, and the development of sustainability capabilities. Studies from Renwick et al. (2016) received 268 citations and demonstrated significant progress in environment-based workforce management. This is followed by Awan et al. (2021), which suggests an integrative framework that uses knowledge acquisition capabilities to enhance green product innovation. Finally, a study by Pinzone et al. (2019) also investigated the effect of green training on pro-environmental behavior and job satisfaction. The topic of green competencies in responding to global environmental challenges has both academic and practical relevance, as shown in this citation pattern. Competency-based approaches have

become a strategic cornerstone in the transition to sustainable development, as demonstrated by the dominance of research focusing on green practices, green innovation, and capability development in citation patterns.

The Most Productive Authors and Co-Citations of Authors

The distribution and contribution of authors in bibliometric analysis aim to identify authors who most often publish articles related to green competency studies (Chozo, 2024). Authors who are productive in publishing scientific articles are typically measured by the number of publications and citations they receive. This is to explain the author's extensive research, both empirical and conceptual, related to green competence. Table 6 highlights the credibility of authors who have written two or more articles on green competence. The other authors are not mentioned because there is only one publication.

Table 6. The most productive authors

Author	Total citations	Total link strength
Jabbour C.J.C.	117	4476
Sarkisi, J.	130	4034
Sarstedt M.	113	3628
Ringle C.M.	85	3080
Zhu Q.	86	2917
J.F.	86	2800
Govindan K.	57	2049
Wang y.	79	1924
Liu y.	74	1879
Chen Y.	62	1854

Source: Scopus Database

Observations in Table 6 indicate that the co-authorship of each author is a notable element. Joint citations occur because of the conceptual, methodological, and thematic relationships between the works cited by several authors (Gupta et al., 2023; Robledo-Giraldo et al., 2023). The most prolific and influential authors in green competency studies such as Jabbour C.J.C. (117 citations, link strength 4476), Sarkis J. (130 citations, link strength 4034), Sarstedt M. (113 citations, link strength 3628), and Ringle C.M. (85 citations, link strength 3080) have led a wave of research that has directly impacted the green HRM framework around the world.

These important figures not only support the Green HRM theory but also help organizations achieve the SDGs through their work, as a study from Jabbour & de Sousa Jabbour (2016) emphasizes that green-oriented human resource management and the implementation of environmentally friendly practices in the supply chain are critical components in achieving the various Sustainable Sustainability Goals (SDGs), especially those related to social, economic, and environmental sustainability. In addition, authors who have made significant contributions in a particular field are often cited as a standard reference. Figure 8 shows a group of joint quotes from the authors in the field of "green competence" consisting of 5 different color components.

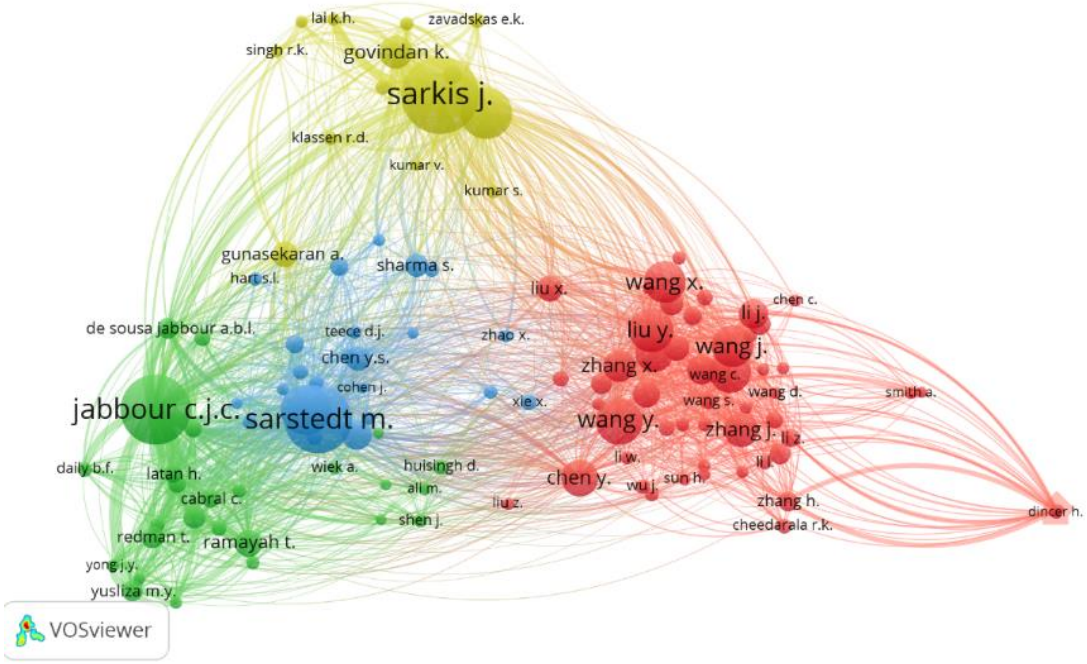

Figure 8. Co-Citation Network of the Authors in the Collected Sample.
Source: Data processing using VOSviewer

The group of authors most frequently cited simultaneously in green competency-related studies is represented by five main groups, as shown by the visualization of the co-author's citation network in Figure 8. Figure 8 shows the relationship between each cluster and the others. In this context, the more recognition the author receives, the more interconnected nodes accumulate. Citation relationships also tend to occur between authors of the same color group. The most dominant cluster is the red cluster, comprising 52 authors, with Wang Y as the primary character. This cluster highlights the significant contribution of innovation-based research and green policies in the Asian region. In addition, the green cluster of 26 authors, with Jabbour CJC as the most affected author, emphasizes green human resource management and organizational sustainability.

The blue cluster, comprising 24 authors, is led by Sarstedt, M. This cluster makes significant contributions to the study of green competencies, utilizing methodological approaches such as structural models and quantitative data analysis. The yellow cluster led by Sarkis J consists of 16 authors who emphasize sustainability-based decision-making and green supply chains. However, the purple cluster, of which Zhao X is the sole author, reflects a different specialty but remains relevant in the context of this study. This network structure indicates that authors with central positions have a significant influence on determining the direction and theoretical foundation of the global green competency literature.

Future Research Directions

This bibliometric analysis provides three main theoretical contributions to the study of green competencies. The results of the study confirm the multidisciplinary nature of this concept, which serves as a link between various scientific fields, including human resource management, continuous innovation, and organizational behavior theory. Several elements, such as the diversity of core journals and variations in key terminology (e.g., green HRM, sustainable innovation, and environmental training), indicate that an analytical approach to green competencies requires a comprehensive, cross-disciplinary perspective. These findings also provide the basis for the development of an integrated conceptual framework

that integrates three main dimensions: cognitive (environmental knowledge), affective (ecological commitment), and psychomotor (implementation capability). For further research, three potential development areas are reviewed from conceptual and methodological aspects, geographical and sectoral contexts, and cross-disciplinary integration.

First, from conceptual and methodological aspects. Future research should develop innovative theoretical approaches that extend beyond dominant frameworks, such as resource-based views, institutional theory, and dynamic capabilities. Alternatives such as stakeholder theory, systems thinking, and critical green theory can offer a fresh perspective on the development and implementation of green competencies across various aspects of the organization. Methodologically, longitudinal approaches, field experiments, and mixed methods are needed to comprehensively evaluate the impact of green competencies (Gull & Idrees, 2022; Pham et al., 2019). There are also research opportunities to explore rarely touched perspectives such as complexity theory and Islamic environmental ethics, especially in developing countries. These findings provide a conceptual foundation for future theoretical and applied research. These studies contribute to determining theoretical and innovative future research directions.

Second, in terms of geographical and sectoral contexts. The results of the analysis show that the developed countries (China, the United States, Germany, and the United Kingdom) dominate in the production of knowledge about green competencies. This indicates a geographical imbalance in academic discourse. These findings highlight the need to expand research to developing countries and the Global South region to understand contextual variations in the implementation of green competencies (Ishaq et al., 2024). A cross-border comparative approach can reveal the influence of socio-cultural factors and local policies on sustainable human resource development. It is essential to expand the study to sectors such as agriculture, micro and small enterprises (MSMEs), and secondary education to develop a more inclusive and locally relevant green competency framework (Pavlova, 2018).

Third, in terms of cross-disciplinary integration. Future research should explore the convergence between green competencies and digital transformation, particularly in the application of AI, blockchain, IoT, and Big data for achieving resource efficiency and innovation on a sustainable basis, as seen in the study conducted by Ghobakhloo et al. (2021). Approaches to understanding the evolution of green skills in an era of technological disruption are needed as an interdisciplinary approach that combines management, engineering, and social science perspectives can uncover these dynamics. Furthermore, empirical research on the impact of green competencies on organizational performance necessitates the development of culturally valid measurement tools. Methods such as case studies and action research can bridge the gap between theory and practice across different sectors.

CONCLUSION

The study of green competencies is gaining popularity among academics, particularly following a global campaign to reduce carbon emissions and achieve the Sustainable Development Goals. Research publications and citations on green skills increased rapidly from 2014 to 2024. Journals such as Sustainability Switzerland, the Journal of Cleaner

Production, and Business Strategy and the Environment can serve as primary reference sources for finding the latest articles that can be used as a basis for further research. The United States, Malaysia, and China are among the countries with robust global initiatives and research infrastructure to support sustainable development. This is evidenced by the many publications related to the topic of green competence. Sustainable development, green competence, and environmental performance are the most commonly used publication keywords related to green competence, as the focus of the discipline shifts annually. Several authors, including Jabbour, C.J.C., Sarkis, J., and Sarstedt, M., are major contributors to this field.

The study not only examines the dynamics of publications and citations related to green competencies from 2014 to 2024, but also highlights the most significant clusters of authors, countries, and topics in the discussion of the SDGs, thereby strengthening the theoretical foundations of Green HRM. In practical terms, the findings of this study provide a blueprint based on six green competency components that can be adopted by the Learning and Development, HR Policy, and operational management divisions to develop training modules, recruitment policies, and performance metrics that support the achievement of the Sustainable Development Goals (SDGs). Future research can lead to the development of a framework that can be used to assess green competencies across various industry sectors, including Islamic Banking. In addition, the results of this research can also serve as evaluation material for assessing how technology can enhance green capabilities in sustainability practices. Thus, this study not only describes how the study of green competencies develops bibliometrically but also emphasizes its role as a driver of sustainable development.

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