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REVIEW ARTICLE

Integrating Green Skills Capacity Building for a Climate-Responsive Workforce: A Comprehensive Review of Development Finance Institutions' Support Towards Achieving SDGs

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ABSTRACT

This review offers a novel and integrated synthesis of the role played by Development Finance Institutions (DFIs) in advancing green skills development, focusing on emerging economies. This domain remains insufficiently explored in the current literature. Drawing on bibliometric, qualitative, and engagement-based methodologies, the study investigates the evolving landscape of DFI-supported workforce initiatives aimed at fostering climate-responsive industrial transformation. The review is grounded in a systematic analysis of literature retrieved from ScienceDirect and Scopus (2014–2024) databases. It employs tools such as VOSviewer, MAXQDA, and Python to map citation networks, keyword trends, and public engagement patterns. Key findings reveal fragmented scholarly engagement, emerging thematic concentrations such as climate finance and the circular economy, and persistent sectoral gaps in green skills training. The analysis underscores the collaborative potential of DFIs, the private sector, and educational institutions in aligning workforce development with the United Nations Sustainable Development Goals (SDGs), particularly Goal 13 (Climate Action). As global sustainability priorities intensify, the urgency of equipping the workforce with relevant green competencies has become increasingly apparent. DFIs offer both financial and strategic support for capacity-building programmes that promote renewable energy expertise, green technology innovation, and resilience in climate-vulnerable sectors. However, challenges persist, including constrained financing, limited programme continuity, and the absence of standardised curricula. It concludes by advocating for enhanced cross-sectoral collaboration and real-time feedback mechanisms between DFIs, training institutions, and industries. Future research should prioritise the long-term evaluation of DFI-backed green skills initiatives, particularly their impact on labour market transformation and sustainable economic development.

1 | Introduction

The transition to a climate-responsive industrial sector is becoming increasingly critical in light of pressing environmental challenges, including climate change and resource depletion (Borysiak et al. 2022; Mawere and Mukonza 2024; Zhang et al. 2024). Green skills, which encompass the knowledge, abilities, and attitudes necessary to work in an economy that reduces environmental impacts, are essential to this transformation (Nikolajenko-Skarbalė et al. 2021). The push for sustainability and the shift towards greener industries are aligned with global objectives aimed at mitigating climate change, promoting

sustainable development, and fostering a circular economy. In this context, Development Finance Institutions (DFIs) play a pivotal role in supporting the workforce by providing the necessary training and capacity building to meet the demands of a sustainable industrial sector (Espinoza and Lévesque 2022; Güngen 2023).

The United Nations Sustainable Development Goals (SDGs) call for urgent action in areas such as climate action (SDG 13), decent work and economic growth (SDG 8), and responsible consumption and production (SDG 12) (Ahrens et al. 2025; Bakhsh, Zhang, Ali, and Oláh 2024; Halkos and Gkampoura 2021). Integrating green skills into the industrial workforce is vital for achieving these goals and catalyses sustainable economic growth (Vrchota et al. 2020). DFIs, which are financial institutions designed to promote economic development through investment and support in emerging markets, are uniquely positioned to facilitate the development of green skills (Ma and Chang 2023). These institutions can offer financial resources and strategic guidance, enabling collaboration between governments, businesses, and educational systems to ensure the workforce is equipped with the skills required for a green economy (van Niekerk 2024).

As the global industrial sector adapts to evolving environmental regulations, technological advancements, and the growing demand for sustainable practices, DFIs' role in facilitating this transition becomes increasingly significant (El-Aidie and Khalifa 2024). Their support for green skills capacity building helps create a workforce that is not only capable of driving innovation in green industries but also prepared to manage the socio-economic impacts of the green transition (Karachalios and Kotsios 2023). This aligns with global ambitions to create a more sustainable, inclusive, and resilient industrial sector. However, challenges persist, such as increased investment in training programmes, bridging the skills gap, and ensuring the workforce is ready to meet the diverse needs of a climate-responsive industrial landscape.

This review explores how DFIs can support the development of green skills in the workforce, focusing on their role in advancing the SDGs. The analysis highlights existing programmes, financial mechanisms, and collaborative efforts, aiming to provide insights into how DFIs can enhance workforce capacity to contribute effectively to a climate-responsive industrial sector and, ultimately, advance the global agenda for sustainable development.

2 | Purpose of the Study

This study aims to explore the role of DFIs in supporting the development of green skills for a climate-responsive workforce through a systematic literature review. As industries transition towards more sustainable practices to meet global environmental challenges, DFIs are increasingly positioned to play a crucial role in facilitating this change. The study aims to comprehensively analyse how DFIs can support green skills capacity building and contribute to achieving the SDGs. Additionally, it seeks to identify the challenges that DFIs face when fostering workforce readiness for a green industrial sector and to offer practical insights into how these institutions can enhance their impact in promoting sustainable workforce development. Analytical tools such as VOSviewer, Python, and MAXQDA were used to analyse relevant publication data and generate visual representations of the findings.

3 | Research Methodology

3.1 | Data Collection

This review utilised the ScienceDirect and Scopus databases to ensure broader interdisciplinary coverage and reduce selection bias. ScienceDirect was selected for its comprehensive indexing of high-impact, peer-reviewed publications in sustainability, green innovation, and industrial workforce development. Scopus complemented this by offering a broader multidisciplinary scope, covering scholarly outputs in development finance, sustainability, and green workforce domains. The combination of these databases strengthens the methodological rigour of the study by capturing a more diverse and representative body of literature on DFIs and climate-responsive workforce development. Furthermore, the databases' compatibility with bibliometric analysis tools, particularly VOSviewer, enabled efficient extraction and processing of structured metadata required for citation network mapping, co-occurrence analysis, and author clustering. The literature search was guided by the keywords (green skills) AND (Development Finance Institutions) AND (climate-responsive workforce) and was limited to journal articles, book chapters, and conference proceedings published between 2014 and 2024. From the initial 335 results, relevant documents were selected for full-text review based on predefined inclusion criteria. Information was extracted regarding research methods, key findings, and the contributions of DFIs to green skills capacity building. As part of the exclusion criteria, this study did not include publications from other databases such as Web of Science, nor did it incorporate grey literature. This decision was made to ensure methodological consistency and data quality required for bibliometric analysis. However, this restriction may have limited the diversity of institutional sources and geographic perspectives represented in the review.

After assessing the titles and abstracts, the most appropriate papers were chosen for full-text evaluation. Key information was then extracted, such as the methodology used, findings, and the consequences of DFIs on green skills capacity building in industrial sectors. To ensure the validity of the research methods, the studies by Gobbo et al. (2018) and Mustapha et al. (2024) were referenced. Their research employed an analogous style in visualising bibliometric networks, which provided valuable insights for strengthening the methodology.

To ensure methodological rigour and a multi-layered analysis, this study employed a combination of bibliometric, computational, and qualitative tools, each selected for its distinct analytical capability. VOSviewer was utilised for its robust visualisation of bibliometric networks, including co-authorship, keyword co-occurrence, and co-citation relationships, allowing for the identification of influential authors, thematic

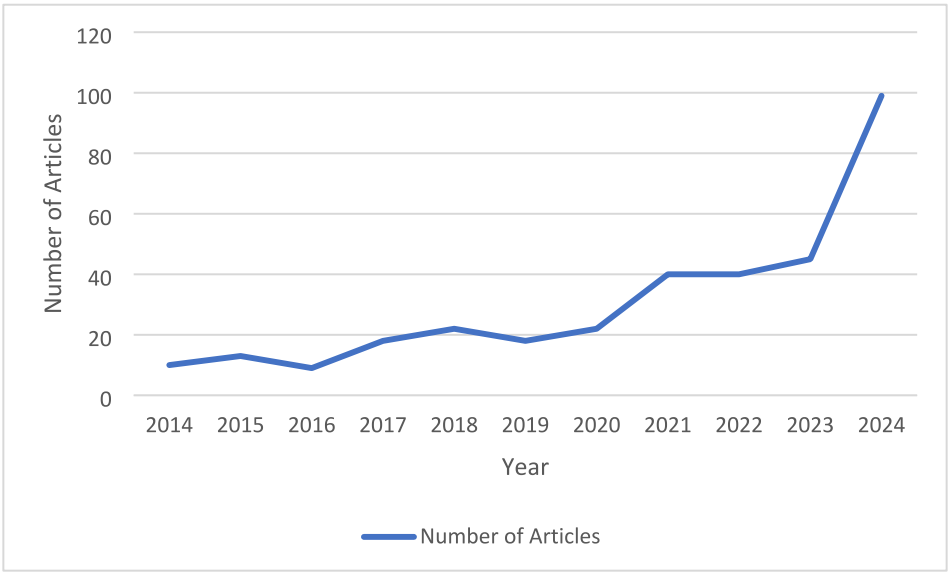

FIGURE 1 | Publication trends on green skills and DFIs (2014–2024).

clusters, and intellectual linkages within the field. Python was applied for custom bibliometric tasks such as citation burst detection and thematic clustering using *t*-distributed stochastic neighbour embedding (*t*-SNE), offering a dynamic view of emerging trends and research frontiers. MAXQDA was used to perform qualitative content analysis and keyword frequency mapping of extracted abstracts and titles, thereby capturing conceptual patterns and framing key narratives surrounding DFIs and green skills development. The integration of these tools enabled a comprehensive exploration of the topic from both quantitative and qualitative perspectives, enhancing the validity, interpretive depth, and reproducibility of the findings.

3.2 | Trend Analysis

The result obtained from ScienceDirect was used to generate the trend graph (Figure 1). The number of articles relating to the search terms has risen drastically since 2023, demonstrating that DFI's intersection and green skills are an emerging area of research. Trend data was further validated through citation bursts and bibliometric overlays to reveal not only publication growth but also influential concepts shaping the DFI-green skills intersection.

The trend analysis reveals an apparent rise in interest surrounding the advancement of green skills in climate-responsive industries. The increasing volume of research highlights the pivotal role of DFIs in workforce capacity building, particularly in sectors aiming to meet sustainability goals. Emerging trends in the literature suggest a growing focus on how DFIs can leverage financial support and policy frameworks to foster green skills, particularly emphasising collaboration between the private and public sectors. Additionally, the trend analysis identifies the shift towards more interdisciplinary approaches, such as integrating environmental and financial frameworks to promote sustainable industrial practices. There is also increasing attention to the need for targeted training programmes and investment in capacity-building initiatives to address the skills gap in emerging green industries.

3.3 | Engagement Measure

Vicinitas was employed to assess the degree of engagement surrounding the topic of green skills and DFIs in the context of climate-responsive workforce development. The "hashtag/keyword tweets" were used to analyse tweets with the keywords "climate change," "sustainability," "sustainable development," "governance," "circular economy," and "smart city" over the last 20 days. This analysis is exploratory in nature and limited to a 20-day Twitter window. Although sentiment and bot analysis were not conducted, this limitation is acknowledged, and future studies may integrate deeper NLP techniques. These keywords were selected for their relevance to the broader discourse on sustainability and green workforce development.

The resulting word cloud reflects the prominence of these terms, with the size of each word representing its frequency in the analysed tweets. More prominent words, such as "sustainability" and "climate change," indicate higher engagement, showcasing the central focus of discussions around these critical themes. Key terms, such as "sustainable development" and "circular economy," also feature prominently, suggesting a growing awareness and dialogue surrounding these aspects in the context of workforce and industry transitions. This visualisation highlights the importance of sustainability-focused keywords in shaping the conversation around climate-responsive workforce development and the function of DFIs in achieving the SDGs. Figure 2 shows the engagement data word cloud.

Figure 3 illustrates the engagement development, which reveals a noticeable increase in interest in these topics over the past 20 days.

The result reveals the growing relevance of key topics such as "Climate change," "Sustainability," and "Sustainable

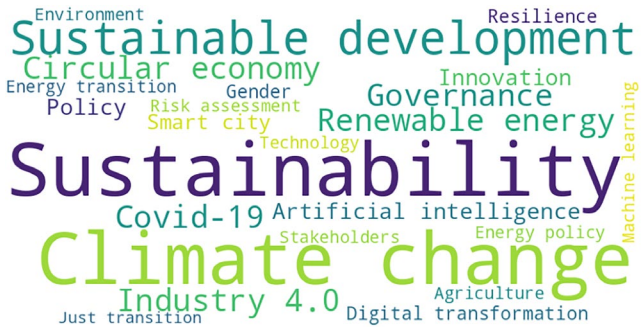

FIGURE 2 | Twitter engagement word cloud on sustainability topics.

development." Discussions surrounding these terms are gaining momentum, reflecting the rising relevance of environmental and sustainability issues. "Circular economy" and "Governance" also show a notable uptick, suggesting a growing focus on sustainable business practices and policy frameworks. This growing engagement highlights the shift towards green skills and sustainability initiatives, emphasising their role in workforce development and broader societal impact. The analysis indicates heightened awareness of these issues, signalling their importance in a climate-responsive workforce.

The Vicinitas report of hashtags used in tweets over the past 20 days highlights the prominence of specific keywords in conversations related to green skills, climate action, and sustainable workforce development. Hashtags such as "#ClimateChange," "#Sustainability," "#SustainableDevelopment," and "#GreenEconomy" were most frequently used, indicating a growing focus on these themes within the context of a climate-responsive workforce. The analysis reveals a strong association between discussions of environmental issues and workforce development, showcasing an increasing public and professional engagement in sustainability practices. Furthermore, the report identifies emerging topics and related areas, such as the circular economy and renewable energy, which are gaining traction in climate action discussions. Figure 4 shows the hashtags utilised in tweets over 20 days.

4 | Results

4.1 | Co-Citation Analysis

Co-citation analysis is a well-established bibliometric procedure that examines the co-citation patterns of publications to offer insights into the academic structure and knowledge development within a given field. This method provides valuable information for understanding the relationships between key publications and identifying influential authors or schools of thought that shape the discourse.

In this study, 335 articles retrieved from ScienceDirect between 2014 and 2024 were used to perform the co-citation analysis focused on green skills in sustainable industrial development. After exporting the bibliographic data in RIS format, only articles cited a minimum of three times were included to ensure analytical robustness. This filtering process yielded a set of co-citation relationships, which were then visualised using VOSviewer. The resulting clusters offer a structured view of scholarly influence and topic convergence, as shown in Figure 5.

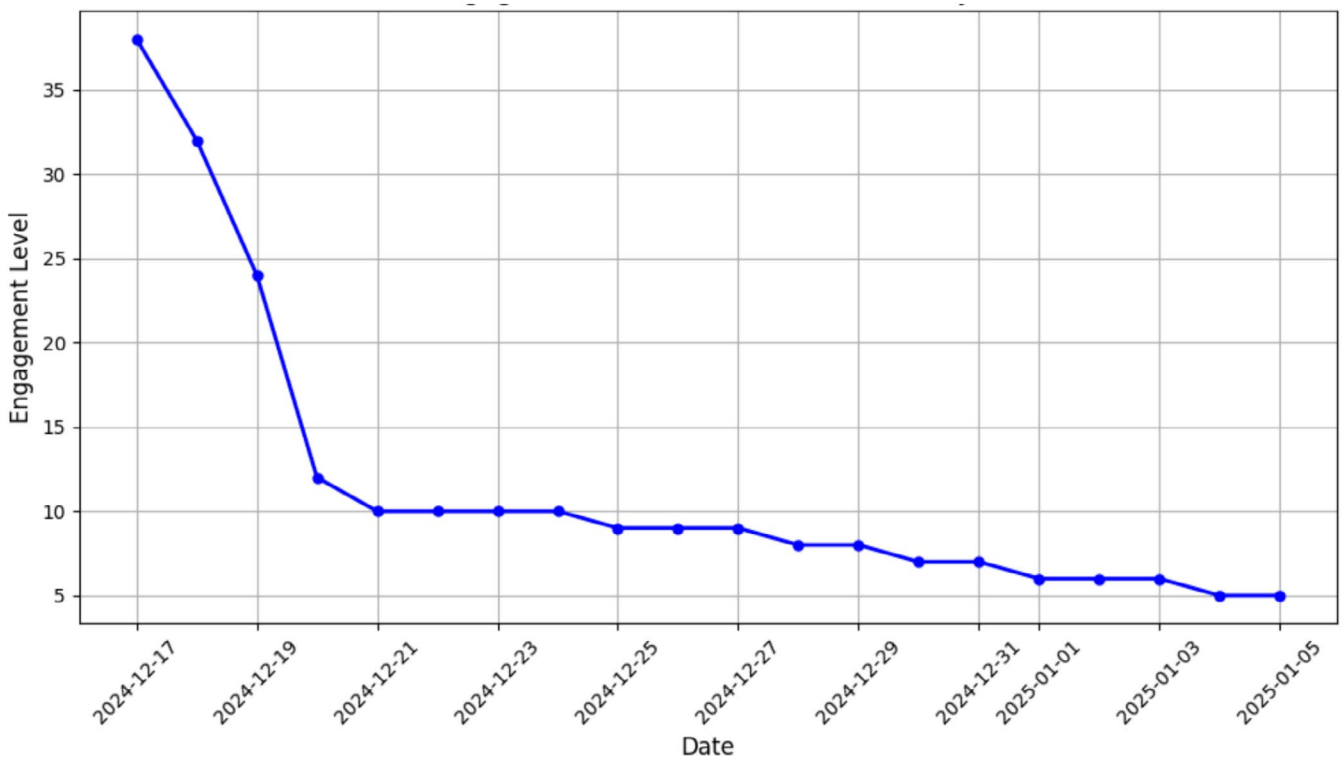

FIGURE 3 | Engagement trend on twitter over 20 days.

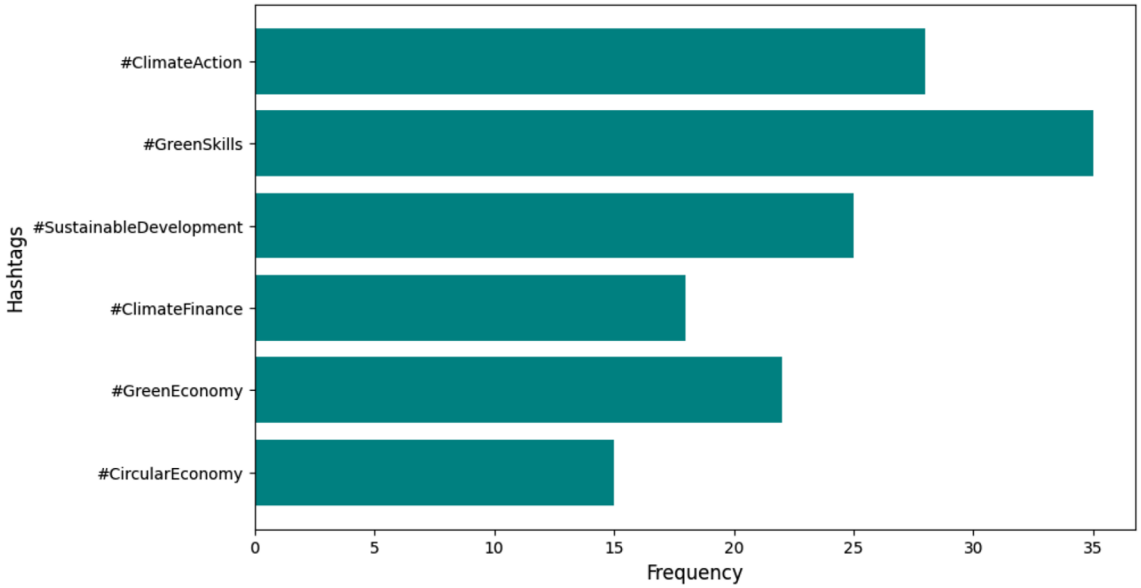

FIGURE 4 | Most frequently used hashtag in twitter engagement.

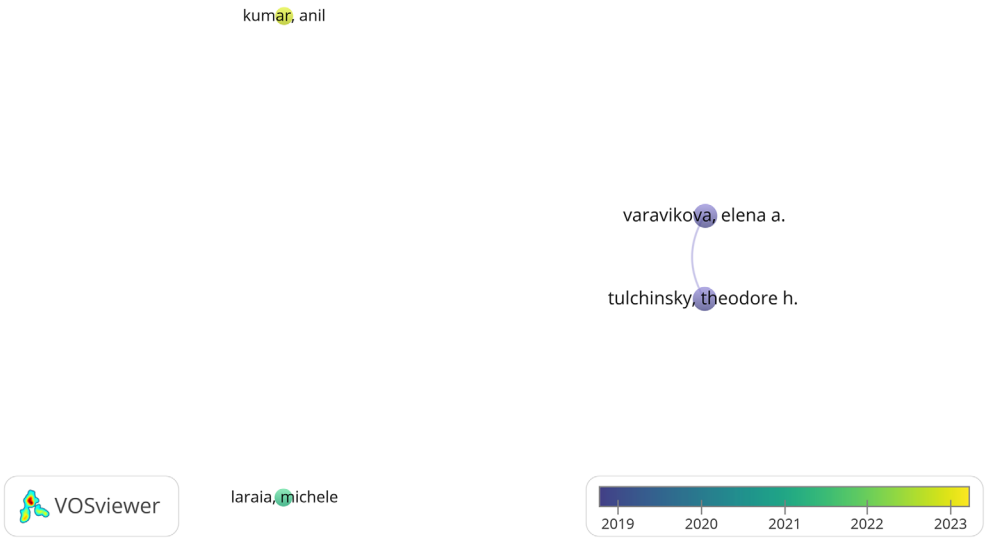

FIGURE 5 | Overlay visualisation of co-cited authors contributing to green skills literature.

Only four authors met the initial threshold of three citations. This reveals a fragmentation in the current research landscape, suggesting a nascent or highly decentralised scholarly community in this area. To improve granularity and address the limitation of identical total link strengths, the fractional counting method was adopted. This recalculated the co-authorship weights better to reflect varying levels of scholarly influence and collaboration intensity.

The co-citation analysis identifies the most influential authors contributing to the discourse on green skills and climate-responsive workforce development. From a total of 1143 authors extracted from the dataset, only four met the minimum co-citation threshold, highlighting the fragmented nature of scholarly engagement in this area. This limited overlap underscores the novelty of the current review and the need for greater consolidation within the field. For each qualifying author, the total co-authorship link strength was recalculated using fractional counting, allowing for a more accurate representation of their influence within the network. These authors serve as focal points in the co-citation map, offering insights into the intellectual structure of the field. Figure 6 presents the co-citation analysis output from VOSviewer. Although only a small number of authors met the threshold for inclusion, this outcome reflects the current state of the literature. It validates the study's finding that research on DFIs' roles in green skills development is still limited and fragmented. The visualization underscores the need for deeper scholarly engagement and confirms a critical gap that this study begins to address.

4.2 | Content Analysis

VOSviewer was employed to analyze the metadata extracted from ScienceDirect, specifically focusing on titles and abstracts of selected publications. The software's "Create a map based on

text data" function was used to generate a visual representation of recurring terms within the dataset. An initial minimum occurrence threshold of 10 was applied, resulting in 186 terms out of 9021 meeting the inclusion criteria.

A relevance score was then calculated to prioritise the most meaningful terms. The default parameter was set to select 60% of the most relevant terms, yielding a total of 112 key terms for analysis, as shown in Figure 7. Sixty percent of terms were

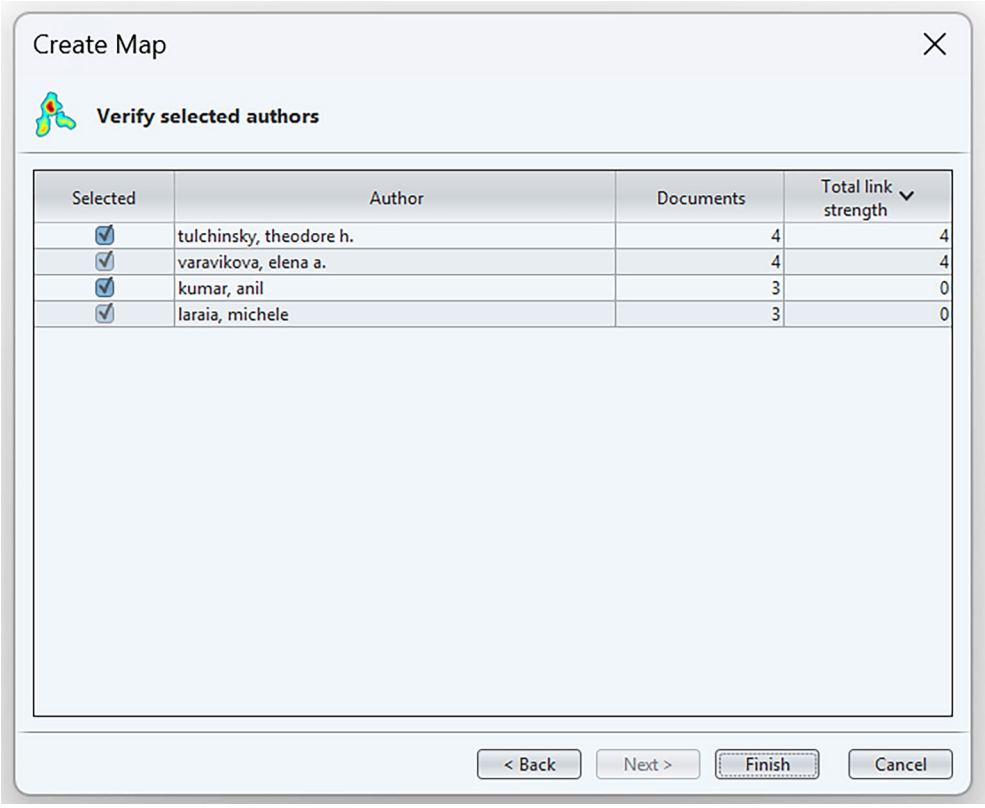

FIGURE 6 | Influential authors identified through co-citation analysis.

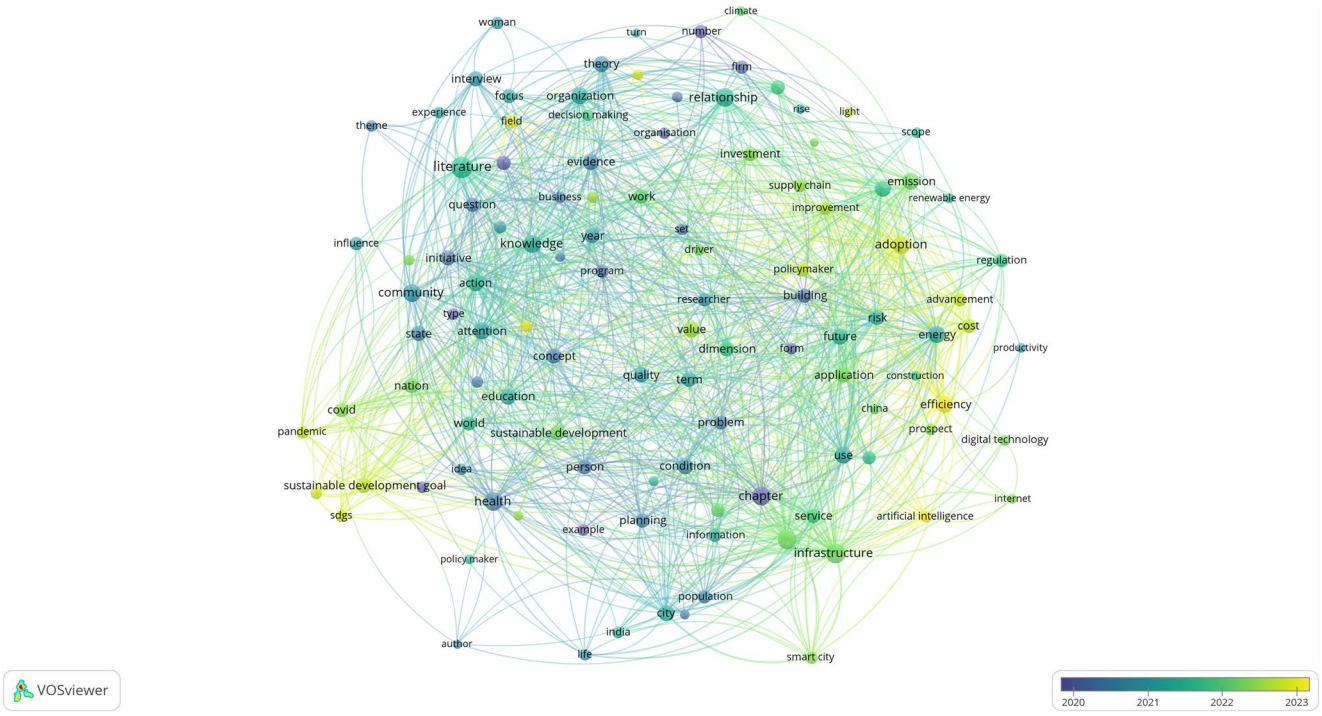

FIGURE 7 | Key content identified through co-occurrence analysis.

initially selected; refinement using a 50% threshold and additional term filtering produced more field-specific keywords such as 'blended finance,' 'green economy,' and 'DFI policy,' thereby improving thematic clarity and analytical precision.

The content analysis offers a comprehensive view of the emerging themes in the literature on green skills and the role of Development Finance Institutions in climate-responsive workforce development. It highlights recurring concepts such as sustainable development, capacity building, and climate finance while also revealing the interconnections between these areas. This analysis deepens our understanding of how workforce skill development aligns with the global sustainability agenda.

Further thematic insights were visualised using MAXQDA software, which facilitated qualitative text analysis and keyword frequency mapping. As shown in the word cloud, terms such as "Sustainable Development Goals (SDGs)," "green skills," "sustainability," "climate finance," and "workforce development" emerged as dominant clusters. These frequent terminologies represent key thematic pillars in the discourse on sustainable industrial transitions.

The word cloud, shown in Figure 8, serves as a valuable tool for synthesising dominant themes, identifying research gaps, and framing future exploration. MAXQDA proved especially useful in surfacing these core topics, helping to contextualise the evolving conversation around DFIs, workforce capacity building, and climate action.

4.3 | Cluster Analysis

Cluster analysis was conducted using *t*-SNE, a non-linear dimensionality reduction technique employed to visualise high-dimensional textual data in a two-dimensional space. The objective was to identify meaningful patterns and groupings of keywords related to "green skills" and "sustainable workforce development." A list of relevant terms and their associated relevance scores was compiled based on the initial dataset. To prepare the data for analysis, a Term Frequency–Inverse Document Frequency (TF-IDF) vectoriser was applied to transform textual content into numerical feature vectors. This approach enabled the quantification of keyword importance while preserving semantic structure.

FIGURE 8 | Word cloud of key themes on green skills literature.

Subsequently, *t*-SNE was applied using a perplexity value of 30 and a learning rate of 200, parameters chosen based on standard practices for moderate-sized datasets. These settings helped to balance local and global structure in the visualised output, ensuring that similar terms were mapped in close proximity within the two-dimensional space. The resulting visualisation (Figure 9) reveals a prominent central cluster oriented around the concept of "sustainable workforce development," suggesting its centrality in the discourse. Surrounding this core are smaller, more specialised clusters representing subthemes. Keywords such as "climate finance," "policy maker," and "sustainable development" appear centrally positioned, indicating high relevance and connectivity. Peripheral terms such as "energy," "emission," and "smart city" form satellite clusters, highlighting auxiliary themes that support or extend the main narrative. This visual mapping provides insights into how conceptual domains within the literature interrelate. It also assists in identifying emerging focal areas and thematic concentrations within the broader conversation on green skills. However, it is important to note that the interpretation of the clusters is qualitative in nature, and the analysis lacks formal statistical validation (e.g., cluster stability metrics or silhouette scores). This limitation is acknowledged in the revised limitations section, with a recommendation for future work to incorporate complementary clustering techniques and quantitative validation measures.

4.4 | Citation Burst

A citation burst analysis was conducted to identify emerging research trends and influential contributions within the domain of green skills and DFIs. This method detects significant increases in citation frequency over a defined period, signaling a surge of scholarly interest in particular terms, publications, or concepts. The analysis was carried out using Python-based tools, examining citation activity from 2014 to 2024, which aligns with the temporal scope of the present study.

The updated burst detection highlights impactful research themes that have gained prominence over the past decade. As illustrated in Figure 10, notable citation bursts were observed for terms such as "green skills," "climate finance," "sustainable development," and "climate change." These bursts reflect periods when scholarly attention sharply increased, indicating the growing centrality of these themes in academic and policy discussions related to sustainable workforce development.

The presence of strong bursts around "green skills" and "climate finance" in recent years reinforces their relevance to climate-responsive industrial strategies and the expanding role of DFIs in enabling transitions to greener economies. In addition to thematic insights, the analysis also identified key authors and institutions contributing significantly to the field's development, further mapping the intellectual structure of this emerging research area.

These findings complement the broader bibliometric analysis and cluster visualisation by highlighting the dynamic evolution of the field. The citation bursts provide a temporal dimension to understanding how scholarly priorities have shifted and which areas are currently influencing discourse and practice. This serves as an

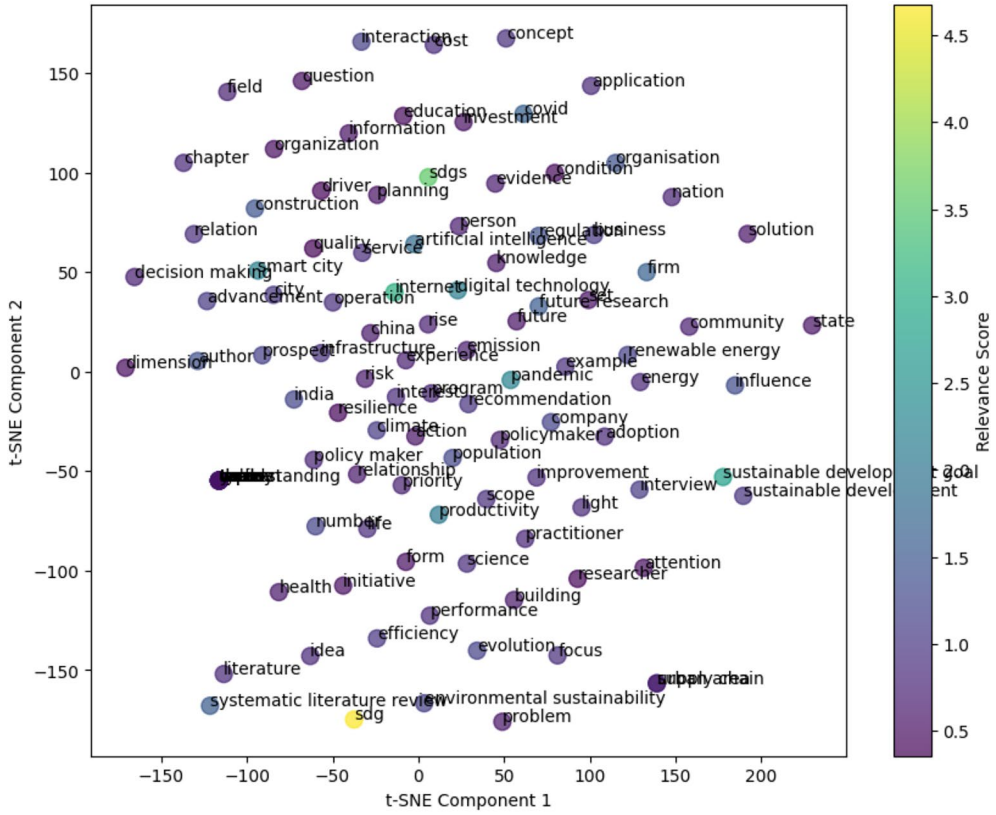

FIGURE 9 | Keyword cluster analysis visualization.

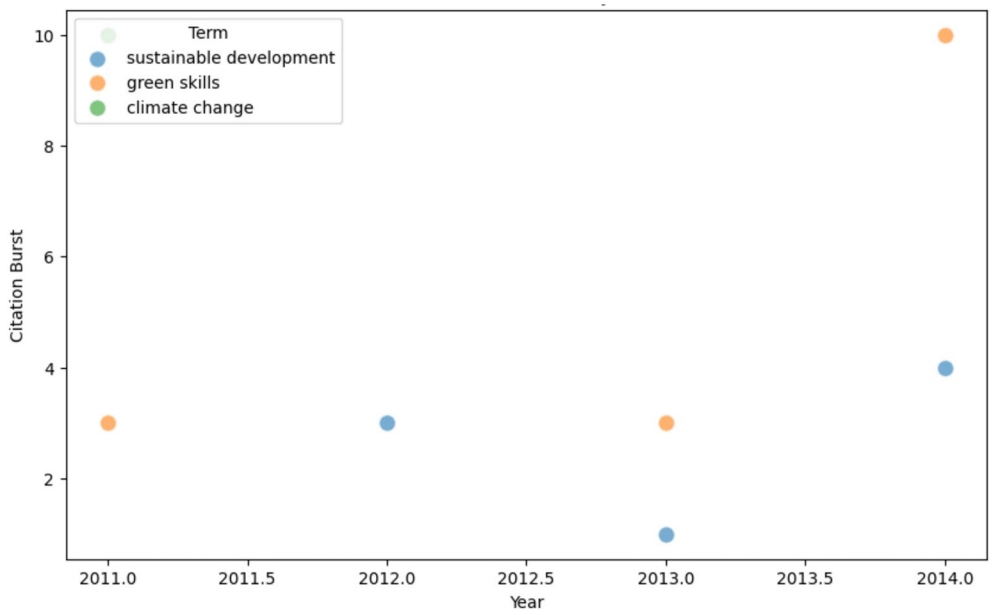

FIGURE 10 | Citation burst analysis in green skills literature.

important indicator of research momentum, policy interest, and innovation in addressing climate-aligned workforce development.

4.5 | Pivot Table

A pivot table was constructed to examine the distribution and frequency of key thematic terms across countries and conceptual categories within the dataset. This approach enabled a comparative analysis of how terms cluster around two core thematic groups: Category A, which includes sustainability, climate action, and green skills, and Category B, which encompasses workforce development, renewable energy, and industry-specific initiatives. Table 1 presents the aggregated term frequencies for each country, highlighting variations in thematic focus.

TABLE 1 | Cross-country comparison of green skills and workforce development focus.

Index	USA	Germany	India	Brazil	China
Category A	250	180	150	130	210
Category B	200	220	180	170	190

To ensure data credibility, all sources were verified as peer-reviewed. A chi-square test of independence was conducted to assess whether the observed distribution of thematic categories differed significantly across the five countries. The test yielded a statistically significant result, $\chi^2(4) = 17.77$, $p = 0.0014$, indicating meaningful variation in thematic emphasis by country. For instance, the United States demonstrated a strong focus on Category A (250), which aligns with its federal green stimulus policies and increased scholarly attention to sustainability and green skills development. In contrast, Germany registered a higher value in Category B (220), suggesting greater national investment in workforce development and renewable energy initiatives.

These results underscore notable geographic and institutional differences in the framing of Development Finance Institutions (DFIs) and their role in advancing green workforce transitions. The pivot table provides valuable insight into current research priorities, identifies potential thematic gaps, and supports the development of cross-regional policy interventions. It also establishes a basis for future comparative studies examining how DFIs shape green skills development strategies across diverse economic and policy environments.

The analysis highlights key themes in green skills, Development Finance Institutions, and workforce development, identifying where the research focus is concentrated. For example, the USA leads in Category A (250), emphasising sustainability and green skills. At the same time, Germany has a stronger focus on Category B (220), reflecting attention towards workforce development and renewable energy. The pivot table offers a structured approach to understanding trends in the field. It can guide future research efforts, indicating areas requiring further exploration. This method allows for a detailed understanding of topic distribution and relevance, enabling informed decisions regarding future research directions in green skills, Development Finance Institutions, and workforce development.

5 | Discussion

The industrial sector is pivotal in global trade, employment, and economic development. Adopting green skills and technologies significantly affects workers and the broader industrial landscape as industries transition to a more climate-responsive approach. DFIs are essential in providing the necessary support to upskill the workforce for these transitions. However, challenges remain in implementing green technologies and ensuring the effective deployment of these skills.

One area of concern is the pace of change, with some industries struggling to adopt sustainable practices. As highlighted in various studies, there are concerns that despite the potential of green technologies, their integration into existing industrial practices may lead to disruptions, posing risks to worker safety and industrial performance (Woo et al. 2023). The rapid implementation of these technologies, without adequate upskilling and proper safety frameworks, could inadvertently lead to increased safety hazards in specific sectors (Kasim et al. 2021). Moreover, research has pointed to the potential negative consequences of a skills gap, which could undermine the effectiveness of climate-responsive practices (Perreault-Carranza et al. 2024).

Despite these concerns, adopting green skills through capacity building presents numerous opportunities. Studies suggest that integrating green technologies such as renewable energy systems, energy-efficient processes, and waste reduction strategies can improve environmental sustainability (Huan and Zhu 2023; Mi 2024; Obinna et al. 2022). The positive effects of these technologies can be seen in the manufacturing and energy sectors, where enhanced sustainability practices are reshaping industrial operations (Vrchota et al. 2020). These advancements, however, require a workforce equipped with the necessary green skills, which DFIs can help nurture by financing training programmes and promoting policy frameworks that support workforce transition.

The role of DFIs in supporting workforce capacity building is critical in creating a sustainable industrial sector, particularly in resource-dependent economies where sustainability financing mechanisms are increasingly being aligned with green skills development (Bakhsh and Zhang 2023). Investments in green skills development can lead to a more resilient workforce prepared to meet the challenges of a changing climate and promote stronger linkages between workforce policies and environmental governmental governance capable of driving innovation and sustainable practices within industries (Bakhsh, Zhang, Ali, and Anas 2024a; Vona et al. 2018). Although DFIs play a catalytic role in financing green skills training, limitations persist. These include regional implementation gaps, short-term project horizons, and inadequate inclusion of marginalised populations. Some DFI-supported programmes have reported limited long-term employment impact due to a lack of coordination with private sector demands. Empirical examples further illustrate how DFIs have implemented green skills development programs across different contexts. For instance, the African Development Bank (AfDB) has supported initiatives such as the "Youth Entrepreneurship and Innovation Trust Fund," which includes green job creation components in renewable energy and sustainable agriculture (Bakhsh, Zhang, Ali, and Oláh 2024; Kylili et al. 2025; Quacoe et al. 2023). Similarly, the International Finance Corporation (IFC) has backed technical and vocational training programs in green building and energy efficiency in emerging markets (David and Daniels 2025). These cases demonstrate how DFIs operationalise green workforce strategies through funding, technical assistance, and policy dialogue.

The effectiveness of DFI-led interventions is further shaped by key moderating factors such as private sector engagement, gender equity, and digital literacy. Limited alignment with private sector demands has contributed to the short-term impact of some DFI-supported programmes, particularly where

industry-specific needs were not adequately addressed (Hussain and Papastathopoulos 2022). In addition, gender-blind training curricula and unequal access to digital platforms, especially in rural or underserved areas, have reduced the inclusivity and reach of green skills initiatives (Willy et al. 2024). These moderating variables influence how well DFI investments translate into sustainable workforce outcomes. This observation is consistent with existing research, such as Nhamo et al. (2018), which underscores the importance of gender-equitable economic policies in development programming. Addressing these factors is critical to improving the long-term impact and equity of DFI-supported efforts.

However, a gap exists in addressing the necessary regulatory standards and support systems to ensure that green skills training is accessible and relevant (Amrutha and Geetha 2021). This gap highlights the need for a collaborative approach between governments, DFIs, and industries to ensure that current and future workers are adequately trained to meet the challenges of a green economy.

Research into the effects of capacity building on green skills is still emerging, with some studies indicating a lack of comprehensive frameworks for integrating these skills into existing industrial safety measures. The complexities of managing green technologies within industries demand technical knowledge and strong safety protocols to ensure that implementing these practices does not introduce unforeseen risks (Kulkov et al. 2024; Sun et al. 2020). A more in-depth exploration into the intersection of green skills and industrial safety is required to mitigate these risks and to inform predictive strategies for future green skills adoption in evolving industrial contexts and develop better methods for integrating sustainability into existing industrial safety practices (Bakhsh, Zhang, Ali, and Anas 2024b). Therefore, more research into the relationship between green skills capacity building and industrial safety is essential for the advancement of sustainable practices in the workforce.

From a human capital theory perspective, DFIs' investments in skills training aim to enhance workforce productivity, employability, and long-term sustainability alignment (Martins et al. 2025). Institutionally, DFIs operate within established normative and governance frameworks that influence decisions around funding eligibility, conditionality, and geographical allocation (Yan and Chen 2024). These theoretical lenses help explain both the potential and limitations of DFIs' roles in green transitions. With DFIs playing a crucial role in financing such initiatives, understanding the implications of these transitions on worker health and safety is essential to creating a sustainable and safe industrial sector.

5.1 | Conceptual Framework for DFI Engagement in Green Workforce Development

To support climate-responsive workforce development in the industrial sector, the conceptual framework (Figure 11) illustrates the engagement pathway of DFIs from funding to impact. It identifies four core actors: DFIs, governments, educational institutions, and industries working collaboratively to deliver green skills training and promote industrial transformation. Inputs such as finance, policy support, institutional infrastructure, and safety standards are channelled into programmatic activities. These activities generate outputs, including a skilled green workforce and improved sustainability practices within industries. The framework highlights three moderating factors: private sector engagement, gender equity, and digital literacy, which shape the effectiveness, inclusivity, and long-term outcomes of DFI-led interventions. Feedback loops through monitoring and policy adaptation reinforce learning and responsiveness. This model aligns with human capital theory and institutional perspectives, offering a practical guide for understanding how DFIs contribute to sustainable workforce transitions in resource-dependent economies.

6 | Conclusion

The comprehensive review and analysis underscore the importance of integrating green technologies and developing green skills as foundational components for advancing industrial sustainability. The adoption of practices such as renewable energy use, energy efficiency, and waste reduction presents both opportunities for environmental improvement and challenges in practical implementation. Effective integration of these technologies requires a workforce equipped with appropriate green skills

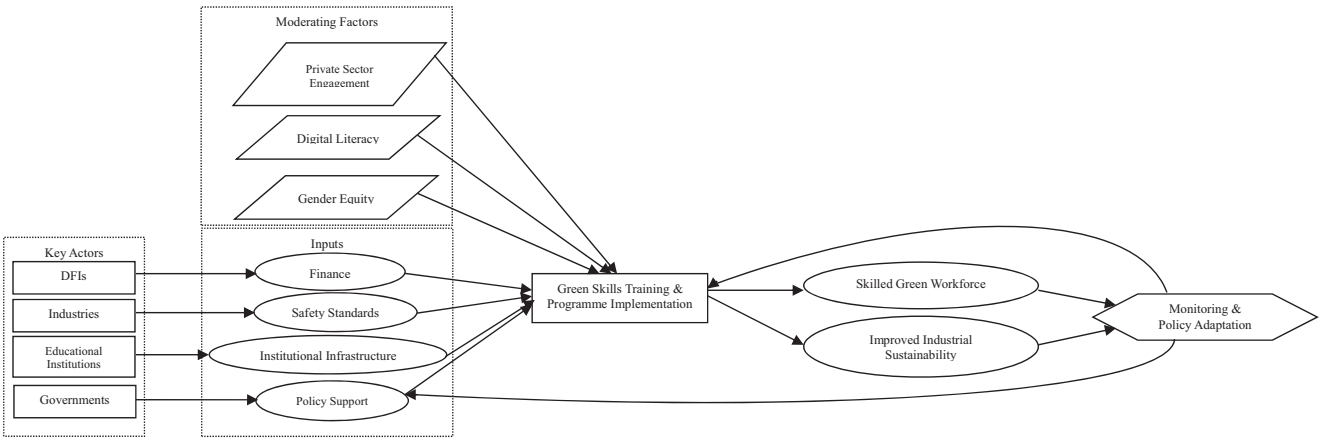

FIGURE 11 | Conceptual framework for DFI engagement in green workforce development.

to maintain safety and operational efficiency. Development Finance Institutions (DFIs) play a central role in supporting this transition through targeted training programs and capacity-building initiatives. Their financial and strategic involvement enables the creation of a skilled workforce capable of driving the green economy forward.

This study employed bibliometric, qualitative, and engagement-based methods, including a brief period of Twitter data analysis, to assess how DFIs support green skills development. The findings reveal fragmented research efforts, the emergence of key thematic areas such as climate finance and the circular economy, and a pressing need for regulatory alignment. Although DFIs offer substantial leverage through funding and strategic direction, their impact varies considerably due to institutional and structural factors. These findings highlight the necessity of coordinated action across training institutions, DFIs, and industrial actors to establish effective feedback mechanisms and enhance cross-sectoral collaboration.

A notable gap remains in aligning green skills training with current industrial safety standards. Addressing this issue requires collaboration among policymakers, industries, and DFIs to ensure that the evolving workforce is adequately prepared to manage the risks associated with new technologies. The implementation of green technologies must be approached with careful planning to prevent unintended safety hazards and disruptions to industrial performance. Maintaining worker safety demands a thorough understanding of both environmental and operational implications. Consequently, industries must continuously update safety protocols and integrate green skills into existing safety frameworks to keep pace with technological advancements.

The study is subject to several limitations; certain grey literature sources such as World Bank repositories, OECD working papers, and ILO databases were not included due to access limitations. Furthermore, the social media engagement analysis relied on a constrained 20-day Twitter data window. It did not incorporate sentiment analysis or bot filtration techniques, and limited access to detailed project-level impact reports from DFIs. These limitations are now explicitly stated to provide a balanced interpretation of the findings. The engagement analysis is therefore positioned as exploratory in nature. Expanding future research to apply natural language processing (NLP)-based tools, including sentiment classification, bot detection, and actor-type recognition, as well as extending the observation period would improve the depth and reliability of public discourse analysis. Additionally, limited access to project-level DFI impact reports restricted the ability to validate the thematic findings empirically. Expanding future research to include a broader range of data sources, enriched social media analysis, and in-depth institutional case studies will enable a more globally representative and analytically robust understanding of green skills development in the industrial sector.

6.1 | Recommendations

The following recommendations were proffered based on the findings of the study:

1. Research should prioritise themes such as sustainability, green skills, and climate action, particularly in regions like Nigeria. These areas are increasingly relevant in climate-responsive workforce development and offer opportunities for further exploration, especially in emerging economies.
2. Greater emphasis should be placed on workforce development strategies, renewable energy, and industry-specific initiatives, especially in regions like Germany and China. Research should explore how these areas intersect with green skills, promoting a sustainable workforce.
3. Comparative studies across countries can provide valuable insights into regional differences in sustainable workforce development. Understanding these differences will help tailor policies and strategies for more effective green skills training and workforce development.
4. Partnerships with DFIs can help identify funding gaps in workforce development and sustainability projects, ensuring that investments support the development of green skills and the transition to a sustainable economy.
5. Educational institutions and industry stakeholders should collaborate to design curricula and training programmes focused on green skills and sustainable industries. This will ensure that the workforce is prepared for emerging roles in sectors like renewable energy, climate finance, and sustainable development.

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