

Enhancing Vocational Education for Green Industry: A Scopus-Based Learning Analysis of Green Skills and Work Readiness

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ABSTRACT

Climate change and environmental degradation have increased the need for sustainable industrial practices, requiring vocational education to prepare graduates with relevant green skills. However, vocational training often fails to meet industry expectations for sustainability competencies. This study systematically reviews the literature on green skills, green industry standards, and workforce readiness using the Scopus database. A total of 38 publications were analyzed through a systematic literature review, bibliometric mapping, and thematic network analysis to identify research trends and conceptual relationships. The findings reveal fragmented integration of green skills into vocational education, particularly in curriculum development, industry collaboration, and experiential learning. The reviewed studies highlight the importance of embedding sustainability principles into vocational curricula to produce environmentally responsible and industry-ready graduates. This review offers a conceptual framework and practical recommendations for educators, policymakers, and industry stakeholders to enhance green workforce readiness and advance sustainable vocational education.

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Introduction

The transition toward a green economy has become one of the most significant global transformations of the twenty-first century. Governments, industries, and educational institutions

are increasingly expected to contribute to climate change mitigation, sustainable production, and the development of environmentally responsible human resources. The International Labour Organization estimates that millions of new jobs will emerge from green economic activities, while many existing occupations will require substantial reskilling and upskilling to meet sustainability standards. Consequently, vocational education and training (VET) institutions are under growing pressure to prepare graduates who possess not only technical competencies but also green skills, environmental awareness, and the capacity to adapt to rapidly changing industrial demands (Pavlova, 2019; Cedefop, 2024).

From a theoretical perspective, the relationship between vocational education and green industry can be explained through several complementary frameworks. Human Capital Theory emphasizes that investment in education enhances workers' productivity, adaptability, and employability, while Competency-Based Education highlights the importance of aligning learning outcomes with evolving industrial requirements. Within the sustainability agenda, Education for Sustainable Development (ESD) advocates that education should develop knowledge, skills, values, and behaviors that enable individuals to contribute to environmental protection and sustainable development UNESCO (2023). Furthermore, Green Skills Theory conceptualizes green skills as an integration of technical, cognitive, managerial, social, and environmental competencies required to support low-carbon, circular, and resource-efficient economies Pavlova (2019). Recent literature further argues that green competencies should not be viewed solely as environmental knowledge but as multidisciplinary capabilities that combine innovation, problem-solving, communication, leadership, and digital literacy to facilitate the green transition (Albertz and Pilz, 2025; Demirel et al., 2025). Collectively, these theoretical perspectives suggest that vocational education must evolve from conventional job-oriented training toward competency development that supports sustainable industrial transformation.

Recent empirical evidence consistently demonstrates that green skills are becoming essential requirements across diverse industrial sectors. Environmental regulations and sustainability policies have substantially increased the demand for engineering, technical, and managerial green competencies, particularly in industries undergoing green transformation Vona et al (2018). Employer surveys further indicate that industries strongly expect vocational graduates to possess environmental awareness, resource efficiency competencies, and sustainable production skills in addition to conventional technical expertise Handayani et al (2020). At the organizational level, Green Human Resource Management practices have been shown to strengthen employees'

environmental competencies and improve organizational sustainability performance Bazrkar and Moshiripour (2021). Moreover, employers increasingly emphasize transferable competencies—including critical thinking, communication, collaboration, adaptability, and problem-solving—as fundamental skills required to support the transition toward green economies Strachan et al (2022). Comparative studies also reveal that although many vocational education systems have begun integrating green competencies into their curricula, implementation remains uneven across countries and industrial sectors, highlighting the need for more systematic curriculum reform (Chen, 2025; Albertz and Pilz, 2025).

Another significant gap concerns the integration of employability and sustainability perspectives. Many vocational education studies discuss employability without explicitly addressing environmental competencies, while sustainability studies frequently overlook labor market readiness and vocational pathways McGrath et al (2020). As a result, the relationship between green skills development and work readiness remains fragmented across different research domains Kwok et al (2023). This fragmentation makes it difficult for educators, policymakers, and industry stakeholders to identify priority competencies and effective educational strategies for preparing a green workforce.

The present study offers a novel contribution by conducting a Scopus-based learning analysis of research on green skills and work readiness in vocational education. Unlike previous studies that focus on a single institution, country, or curriculum intervention, this study maps the global development of the field using bibliometric and learning-analysis approaches Donthu et al (2021). The analysis identifies publication trends, leading countries and institutions, influential authors, collaboration patterns, keyword co-occurrence networks, and emerging research themes related to green industry readiness. By synthesizing the intellectual landscape of the field, this study provides a more comprehensive understanding of how vocational education can support the transition toward a sustainable economy.

Therefore, the objective of this article is to analyze the development of research on green skills and work readiness in vocational education through a Scopus-based learning analysis, identify major research trends and emerging themes, and formulate strategic implications for enhancing vocational education to support the green industry transition.

Method

Research Design

This study used a Systematic Literature Review (SLR) approach to collect and synthesize evidence on teachers' digital competence in vocational education. The scope of the study included publications published between 2015 and 2024. The literature search was conducted on electronic databases, namely SCOPUS. The search strategy used a combination of keywords and Boolean operators to cover all relevant studies. Key terms used included TITLE-ABS-KEY ("green skill*" OR "green competenc*" OR "sustainability competenc*") AND ("vocational education" OR "technical and vocational education" OR TVET) AND ("work readiness" OR employability OR "job readiness") Only documents indexed in Scopus were included in the analysis. Each term was matched to the specific syntax of each database. All search results were then exported to a reference management tool and processed to remove duplicates before the filtering stage.

The literature screening followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. PRISMA is an [da1] international guideline designed to improve transparency and reporting quality in systematic literature reviews. PRISMA helps researchers systematically and reproducibly identify, screen, evaluate for eligibility, and include articles. The initial stage involved reviewing titles and abstracts based on pre-defined inclusion criteria of a teacher population in vocational institutions and discussing at least one dimension of digital competence. Studies that only addressed general education, student populations, or hardware aspects without a pedagogical focus were excluded. Next, full-text articles from the screening results were evaluated for eligibility. Reasons for exclusion such as lack of empirical data, not in English or Indonesian, or lack of methodological details were recorded in detail O'Dea et al (2021) , as illustrated in Figure 1.

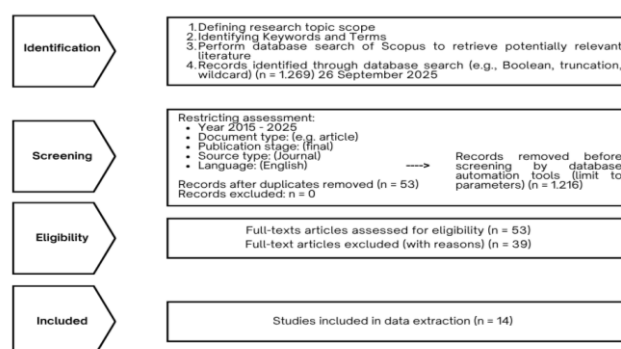


Fig 1: Systematic literature search and screening procedure for the Scopus-based bibliometric analysis.

From Figure 1 illustrates the systematic literature selection process following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The review began with the identification of 1,269 publications retrieved from the Scopus database using predefined search keywords and Boolean operators on 26 September 2025. During the screening stage, automated filtering was applied based on the following inclusion criteria: publication years between 2015 and 2025, document type limited to journal articles, publication status final, source type journal, and language restricted to English. As a result, 1,216 records were excluded through database automation, leaving 53 unique articles for further assessment after duplicate removal. No additional records were excluded during the screening stage. Subsequently, all 53 full-text articles were assessed for eligibility. Following a detailed evaluation, 39 articles were excluded because they did not fully meet the predefined inclusion criteria or were not directly relevant to the research objectives. Finally, 14 studies were retained and included in the data extraction and qualitative synthesis. This rigorous selection process ensured that only high-quality and relevant literature was incorporated into the bibliometric and thematic analysis of green skills and work readiness in vocational education.

Data Screening and Preparation

The study followed the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency during literature selection Page et al (2021). The screening process consisted of four stages: (1) Identification of records from Scopus; (2) Removal of duplicate documents; (3) Screening based on title and abstract; and (4) Eligibility assessment through full bibliographic review.

The inclusion criteria were: (1) articles published between 2015 and 2024; (2) peer-reviewed journal articles; (3) English-language publications; and (4) studies related to vocational education, green skills, sustainability competencies, employability, or work readiness. The exclusion criteria included conference abstracts, editorial notes, errata, book reviews, and publications lacking sufficient bibliographic information.

Learning Analysis

To understand the intellectual evolution of green skills research, a learning analysis was conducted by examining the temporal development of keywords, thematic clusters, and conceptual structures. Keyword normalization was performed by merging synonymous terms (e.g., TVET and Technical and Vocational Education and Training) to reduce redundancy and improve clustering accuracy.

Statistical Analysis

Descriptive statistical analysis was employed to summarize publication characteristics, citation performance, and collaboration patterns. Network statistics generated automatically by Bibliometrix and VOSviewer were used to calculate: (1) frequency distributions; (2) percentage distributions; (3) citation metrics; (4) collaboration metrics; and (5) keyword occurrence frequencies.

Cluster analysis was performed using the Visualization of Similarities (VOS) mapping technique implemented in VOSviewer (Van Eck & Waltman, 2010). Trend analysis was conducted to identify changes in publication growth and thematic evolution over time.

No inferential statistical tests (e.g., t-test, ANOVA, or regression analysis) were performed because the study analyzed bibliographic metadata rather than experimental observations. The findings are therefore presented descriptively through bibliometric indicators and network visualization, consistent with established bibliometric research methodologies Donthu et al (2021).

Result and Discussion

1. Research Trends and Dominant Themes

Research on green skills has expanded significantly over the past decade in response to the global transition toward sustainable development, green economies, and environmentally responsible industries. The increasing demand for a workforce capable of supporting low-carbon and resource-efficient production systems has encouraged researchers to investigate the integration of green skills across higher education, Technical and Vocational Education and Training (TVET), industry, and public policy. Recent studies have addressed diverse aspects of green skills, including sustainability competencies, curriculum integration, environmental regulations, workforce readiness, green human resource management, and innovative teaching and learning approaches.

Although these studies have contributed substantially to understanding the role of green skills in education and employment, the literature demonstrates considerable variation in research focus, methodological approaches, and implementation contexts. While some studies emphasize policy development and organizational transformation, others examine curriculum reform, employer expectations, educational innovation, or workforce competencies required for the green transition. Consequently, a comprehensive synthesis is needed to identify the dominant research themes, methodological patterns, and existing knowledge gaps that can guide future research and curriculum development in vocational education.

To provide a clearer understanding of the current state of knowledge, Table 1 summarizes selected previous studies on green skills, vocational education, and work readiness. The table presents the research titles, authors, key challenges, research methods, and principal findings, thereby illustrating the evolution of green skills research and highlighting major trends that support the development of vocational education for green industry.

Table 1 shows that 24 respondents (42.4%) completed six months of WBL, 18 respondents (32.2%) completed one year, and 16 respondents (25.4%) participated for more than one year. All were drawn from SMK YPPT Garut and had direct hands-on experience in the Automotive Service Workshop Production Unit, numbering 58 participants in total. Student characteristics based on skill level and length of learning. The data are displayed in Table 1.

Table 1. Overview of Previous Research on Green Skills, Vocational Education, and Work Readiness

NO.	TITLE	WRITER	KEY CHALLENGES IDENTIFIED	METHOD	RESULTS
1	Professional development of sustainability competences in higher education: The role of empowerment	Lambrechts W., Verhulst E., Rymenams S. (2017)	Competences; Empowerment; Higher education; Human factors; Professional development; Sustainable development	A constructivist approach combining a literature review, desk research on key publications, and a socio-political analysis.	Identified several professional development (PD) initiatives focusing on sustainability in higher education. Framing these as organizational change processes reveals how empowerment elements are incorporated and can be strengthened to better integrate sustainability competencies.
14.	Innovation for the green transition: challenges and future perspectives	Demirel P., Martinez-Ros E., Quatraro F. (2025)	Climate change risks; Eco-innovation; Firm capabilities; Green skills; Green transition; L2; L5; Q5	Systems perspective and literature synthesis bridging studies on climate change risks, firm capabilities, and environmental policy.	Eco-innovation requires a holistic approach leveraging policy-making, firm governance, sustainability-oriented digital capabilities, and extensive internal and cross-firm collaborations to drive the green transition.

2. The Importance of Green Skills Integration

Several studies indicate that the integration of green skills into Technical and Vocational Education and Training (TVET) curricula remains fragmented rather than systematic (Fuchs, 2024; Adjei et al., 2024). Despite growing attention to sustainability, many institutions continue to face challenges in integrating green competencies into curricula, teaching practices, and competency assessment. These challenges are particularly evident in South and Southeast Asia, where curriculum reform, institutional capacity, and industry collaboration remain limited Wickramasinghe and Wickramasinghe (2026). The following is the topic cluster map of Green Chemistry research, as shown in Figure 2.

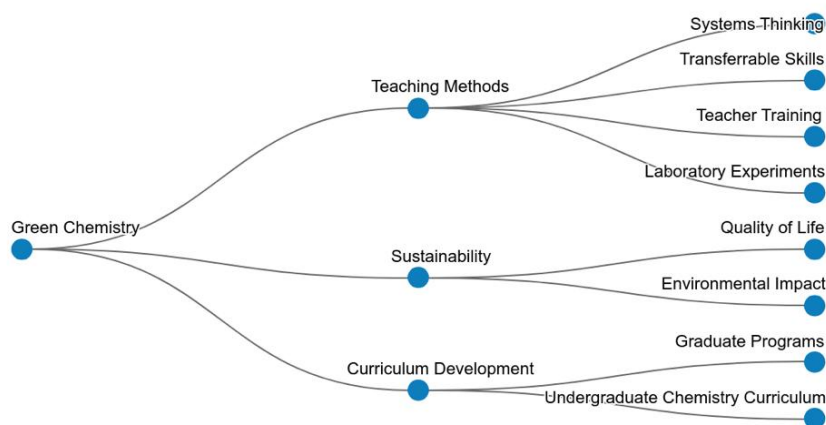


Fig 2: Topic Cluster Map of Green Chemistry Research

Figure 2 presents a topic cluster map generated using the Scopus AI visualization tool, highlighting the conceptual structure of Green Chemistry research. The analysis identifies Green Chemistry as the central theme, connected to three major research areas: Teaching Methods, Sustainability, and Curriculum Development. Teaching Methods emphasizes systems thinking, transferable skills, teacher training, and laboratory innovation, while Sustainability links green chemistry to environmental impact and quality of life. Curriculum Development focuses on integrating sustainability into undergraduate and graduate programs. Overall, the map demonstrates that Green Chemistry has evolved into an interdisciplinary educational framework supporting curriculum innovation, competency development, and sustainable development aligned with the Sustainable Development Goals (SDGs).

3. Work Readiness and Industrial World Expectations

The rapid growth of green jobs has reshaped labor market requirements, creating greater demand for workers who possess both technical competencies and green skills. According to Sofroniou and Anderson (2021), the transition to a green economy is transforming occupational structures and increasing the need for sustainability-related competencies across various industrial sectors. Therefore, vocational education should equip graduates with the knowledge, skills, and attitudes necessary to meet the changing demands of the green labor market.

4. Gap between Education and Industrial Practice

The literature consistently highlights a persistent mismatch between vocational education outcomes and the competencies required by the green industry. Although sustainability has gained increasing attention in TVET, curriculum implementation, practical training, and competency assessment often remain insufficiently aligned with industrial expectations (Fuchs, 2024; Wickramasinghe and Wickramasinghe, 2026). This gap is further exacerbated by limited collaboration between vocational institutions and industry, reducing opportunities for students to acquire authentic workplace experience and green competencies required for the transition toward sustainable production systems (Pavlova, 2014; Adjei et al., 2024).

5. Implications and Recommendations

The findings suggest that vocational education should systematically integrate green skills into curricula by aligning learning outcomes with sustainable industry standards and emerging workforce demands Fuchs (2024). Strengthening partnerships among vocational institutions, industry, and government is also essential to support curriculum development, work-based learning, teacher professional development, and competency certification that reflect the requirements of the green economy (UNESCO-UNEVOC, 2021; Wickramasinghe and Wickramasinghe, 2026). Such collaboration can help narrow the education–industry gap while improving graduates' employability in sustainable industrial sectors.

Conclusion

This Scopus-based learning analysis demonstrates that integrating green skills into vocational education is essential for supporting sustainable industrial development. Research trends focus on four key themes: curriculum integration, industry needs, graduates' work readiness, and policy support. Despite increasing attention, green skills implementation remains fragmented across institutions and countries. Industries increasingly require graduates with technical expertise,

sustainability awareness, digital literacy, and problem-solving skills, while vocational education often lags behind these expectations. Strengthening curriculum reform, industry partnerships, teacher development, and policy support is therefore critical to producing graduates equipped for the green economy and contributing to the achievement of the Sustainable Development Goals (SDGs).

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