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DIGITAL TRANSFORMATION AND SUSTAINABILITY IN EDUCATION: A BIBLIOMETRIC REVIEW.

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Abstract: *The paper provides an overview of research on sustainability and digital transformation in education. It aims to identify the major contributions, major themes, and current trends that have dominated this maturing frame. A bibliometric analysis of 1,435 publications from 2000 to July 2025 that were indexed in the Scopus database was conducted. This enabled the authors to find out the trends of growth in publication, the role played by individual authors, institutions, countries, and co-occurring keywords. The findings indicate that the world is increasingly interested in revolutionising education by using digital technologies that support sustainable, all-inclusive learning conditions. Among the central topics, one is going to mention online and blended learning, the green curriculum design, the digital equity, and the role education plays in accessing the Sustainable Development Goals (SDGs). This study not only traces the academic territory but also examines how technology can be used as an educational tool to promote future-readiness, environmental awareness, and social justice. The results will assist scholars, teachers, and policymakers to make informed decisions and connect innovation to a permanent change.*

Keywords: *digital education, e-learning, sustainability, and sustainability development goals (SDGs)*

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Introduction

The digital transformation of education and the need to ensure sustainability in learning have become dual prerogatives facing learning institutions in all parts of the globe. Since institutions are changing pedagogical delivery and their operations through digital technology, educators must consider introducing environmental values and practices alongside technological innovation (Redecker, 2017). At the same time, the educational goals contained in Sustainable Development Goal 4 (SDG 4) (UNESCO, 2020) express the desire and need to provide inclusive, equitable, and quality education that inspires lifelong learning and promotes sustainable development. The new wave of crises like the COVID-19 pandemic has only increased the pace of the transition to the digitalized mediation of education, opening up both the opportunities and deficiencies in accessibility, infrastructure, and pedagogical equality (Bozkurt & Sharma, 2020). Nonetheless, the digital devices are expected to offer efficiency and cross-continental scope, but the incorporation should be linked with the spirit of sustainability which ensures the sustainability of the ecological environment, social acceptance, and best access (Ng & Wang, 2021). The parallel trends, namely the technological progression and environmental urgency have created the need to pursue a more unified research agenda addressing the ways digital transformation can address the environmental agenda in the world of education.

Although there has been an increasing body of research on digital education and sustainability, research findings tend to be confined by disciplines, regions, or methodological approaches, thus not reaching their full potential. However, much of the scholarly attention is case-based or some sort of conceptual generalisation that lacks a systematic mapping of the changing intellectual framework of the body of knowledge (Donthu et al., 2021). A bibliometric review can thus be used to fill this gap by providing a solid and empirical way to aggregate patterns, reveal prominent players, and follow the history of research topics in the elongated academic realm (Zupic & Cater, 2015). The research, therefore, will give a meta-view of the intersection of the issues of digital change and sustainability in the educational context based on 1,435 publications indexed in the Scopus database between 2000 and 2025. The findings are likely to offer evidence-based knowledge to scholars, practitioners, and policymakers about the strategic integration of technology and sustainability within future-ready education systems.

Research objectives:

1. What are the research trends in digital transformation and sustainability in education according to the year of publication?
2. Who are the most prolific authors in the field of digital transformation and sustainability in education?
3. Which institutions contribute the most to digital transformation and sustainability in education?
4. What are the leading journals publishing on digital transformation and sustainability in education?
5. Which country/territory contributes the most to digital transformation and sustainability in education?
6. What is the dominant subject area published in digital transformation and sustainability in education?
7. What are the most frequently used keywords in research on digital transformation and sustainability in education?
8. What are the main citation clusters of digital transformation and sustainability in education.

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Methodology

Research Design

This research will be conducted on a methodological basis for the analysis of bibliometric information in the sphere of scientific publications covering the issue of digital transformation and sustainability in education. To discuss the tendencies in the field of digital education, e-learning, sustainability and sustainability development goals (SDGs), the study is concentrated on bibliometric mapping.

Literature Search

The Scopus database was found useful in the present research due to the fact that it is among the largest abstract citation databases of peer-reviewed literature, comprising 1435 journals over a global spread. To retrieve the articles that focus on blended learning, green curriculum design, online learning, sustainability and the sustainable development goals (SDGs), a literature search was done on 10 th July 2025 on the Scopus database.

Search Term

The scopus database was used to conduct the search action, since it has all the inclusive journals in the social sciences. The search term was chosen to constitute a wide range of digital transformation, and sustainability. Consequently, the Boolean search string to be applied to the systematic review process will be:

(("digital transformation" OR "digitalization" OR "digitalisation" OR "digital technology" OR "educational technology" OR "ICT integration" OR "technology integration") AND ("sustainability" OR "sustainable development" OR "SDG" OR "sustainable practices") AND ("education" OR "educational institutions" OR "higher education" OR "schools" OR "teaching and learning" OR "curriculum"))

Data Analysis

This study employed bibliometric analysis as the core methodological approach to explore research trends in digital transformation and sustainability in education. The data were extracted from the Scopus database, selected for its comprehensive coverage of peer-reviewed publications across diverse academic disciplines. A Boolean search string combining keywords such as “digital transformation,” “sustainability,” and “education” was used to retrieve relevant documents. The search was limited to English-language publications indexed between 2000 and July 2025. Only articles, conference proceedings, and review papers were included, while editorials, book chapters, and non-peer-reviewed sources were excluded to ensure data quality and consistency.

A total of 1,435 documents met the inclusion criteria. These records were exported in CSV and RIS formats for further analysis. Descriptive statistics were generated to summarize publication trends over time, leading journals, contributing authors and institutions, subject area classifications, and geographical distribution. The visual exploration of the dataset was conducted using VOSviewer, a widely recognized bibliometric visualization software. Co-authorship, keyword co-occurrence, co-citation, and bibliographic coupling analyses were performed to identify dominant research themes, influential contributors, and intellectual structures within the field.

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The results reveal a significant increase in publication activity beginning in 2018, with a sharp peak in 2024, indicating heightened scholarly interest in response to global educational disruptions and sustainability imperatives. Keyword co-occurrence mapping identified four major research clusters, including sustainable development, online learning, educational innovation, and post-pandemic pedagogy. Overlay visualization techniques highlighted the emergence of new research areas such as *generative AI* and *cyber-physical systems* in recent years. Additionally, co-citation analysis identified highly referenced authors, such as *Wang Y.*, *Zhang H.*, and *Bond M.*, whose works serve as foundational literature in this domain.

Overall, the data analysis provides a comprehensive understanding of how the academic community has addressed the intersection of digital transformation and sustainability in education. The combination of quantitative bibliometric methods and visual analytics not only clarifies past and present research patterns but also identifies critical gaps and emerging directions for future inquiry. Researchers, educators, and policymakers may utilise these findings to develop sustainable and digitally enhanced educational ecosystems.

Findings

What are the research trends in digital transformation and sustainability in education according to the year of publication?

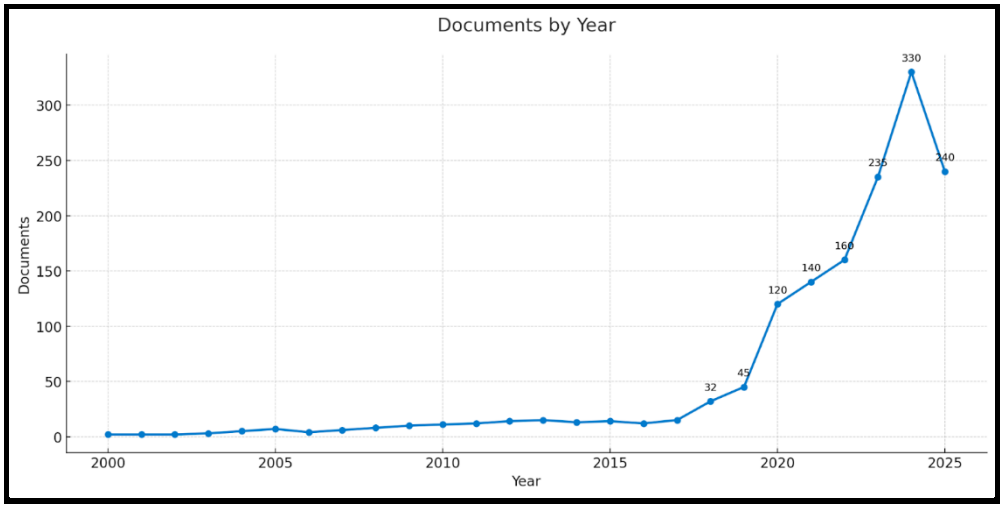

Figure 1: Publication on Digital Transformation and Sustainability According to Years

The line graph describes the development of scientific articles on the topic of digital transformation and sustainability in education annually from 2000 to 2025. As the data indicates, a fairly low level of work can be seen in the first years, and less than 20 documents were published in four years until approximately 2017. Nevertheless, one can observe a noticeable upward trend since 2018 meaning the growing interest of scholars in the subject. This tendency reaches its peak in 2024 when 330 publications are registered, which further implies the active interest in this topic in scholarly circles on the planet, probably stimulated by the further penetration of informational technologies in educational practice and the intensification of sustainable development problems. The fact that the number reduces somewhat in 2025 to 240 publications, however, brings out a healthy and gaining-pace research momentum in this interdisciplinary area.

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Who are the most prolific authors in the field of digital transformation and sustainability in education?

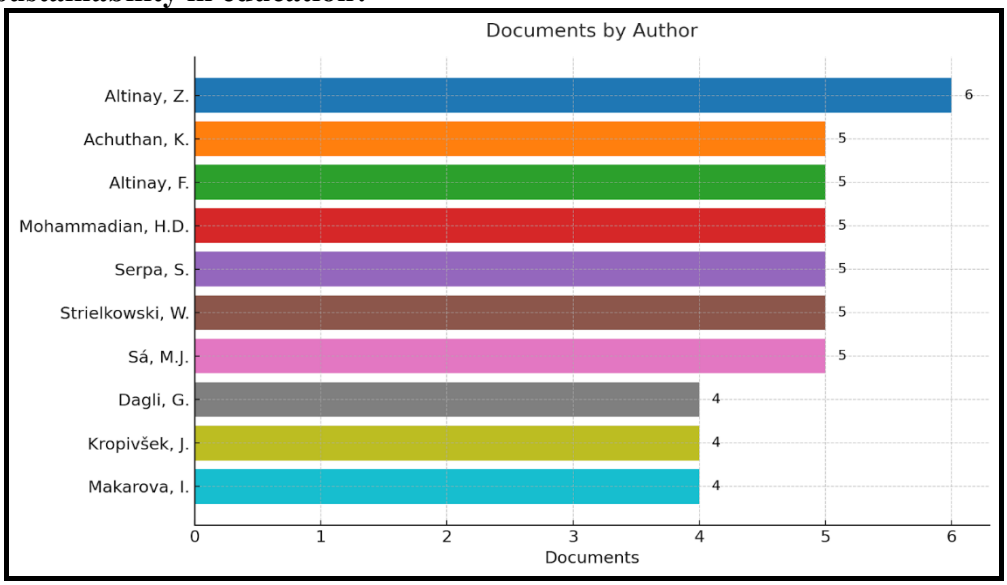

Figure 2: Most Prolific Authors in the Field of Digital Transformation and Sustainability in Education

The bar chart illustrates the publication output of the top ten most productive authors in the field of digital transformation and sustainability in education. Among them, *Altinay, Z.* stands out as the leading contributor with six publications. This position is followed closely by a group of authors including *Achuthan, K.*, *Altinay, F.*, *Mohammadian, H.D.*, *Serpa, S.*, *Strielkowski, W.*, and *Sá, M.J.*, each with five publications. Meanwhile, *Dagli, G.*, *Kropivšek, J.*, and *Makarova, I.* contributed four documents each. The relatively close distribution of publication counts among these scholars indicates a balanced scholarly engagement across multiple contributors, reflecting a collaborative and diverse research landscape in this interdisciplinary domain.

Which institutions contribute the most to digital transformation and sustainability in education?

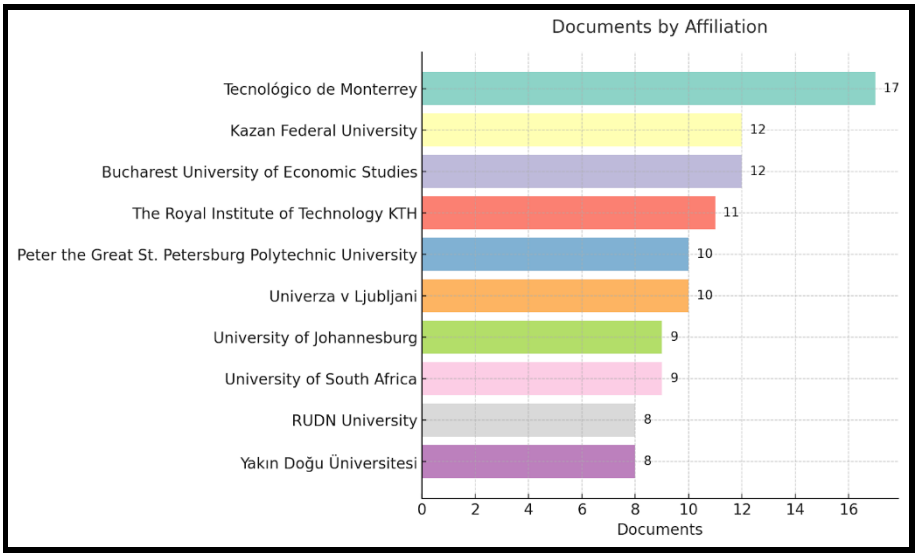

Figure 3: Distribution Of Publications on Digital Transformation and Sustainability in Education by Institutional Affiliation.

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The bar graph demonstrates the translation of scholarly publication by institutional affiliation in the context of digital transformation and sustainability in educational context. The information reveals that Tecnologico de Monterrey is the leader in terms of 17 documents corresponding to the major research contribution in this direction. This is then followed by Kazan Federal University and Bucharest University of Economic Studies with 12 documents each, implying that there is educational activity on the field. Other universities like The Royal Institute of Technology KTH, Peter the Great St. Petersburg Polytechnic University and Univerza v Ljubljani provide between 10 and 11 documents. It is important to note that the institutions belonging to different geographical locations geographically--Europe, Latin America, Africa, and Asia are represented, and it creates the global significance of the study and its interdisciplinary impact.

What are the leading journals publishing on digital transformation and sustainability in education?

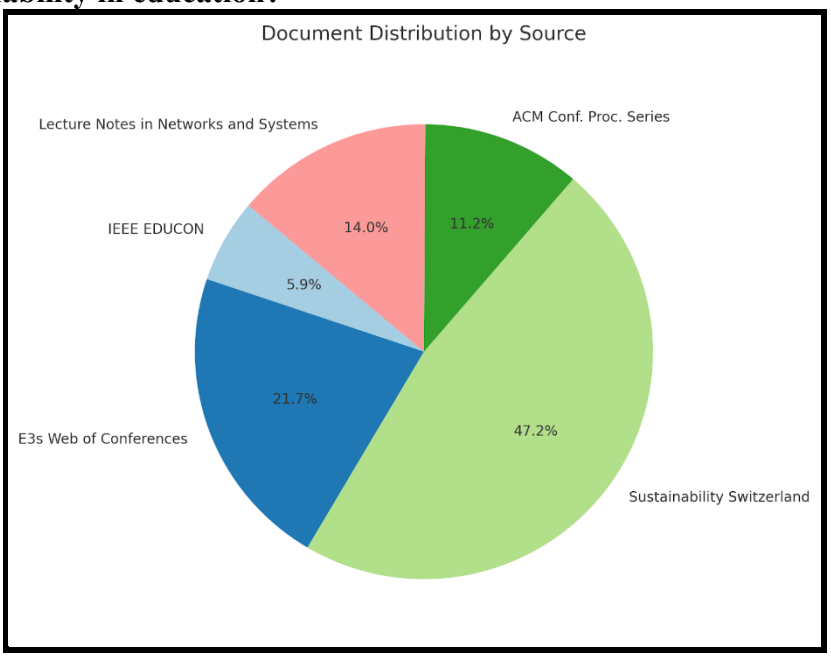

Figure 4: Publication According to Five Major Academic Sources.

The pie chart illustrates how scholarly publications are distributed by source within the domain of digital transformation and sustainability in education. As is obvious, the most conspicuous publication platform is Sustainability Switzerland, which constitutes about 47.2 percent of the total number of documents that will be studied. E3s Web of Conferences follows with 21.7 percent, and Lecture Notes in Networks and Systems takes 14.0 percent of the total output. The other mentionable sources are the ACM international conferencing proceeding series (11.2 percent) and the IEEE EDUCON (5.9 percent). Domination of sustainability-centered and conference-based publications is evidence of interdisciplinary and changing nature of this research, with researchers undertaking the role of sharing research discoveries with their research community at not only high-impact but also academic conferences.

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Which country/territory contributes the most to digital transformation and sustainability in education?

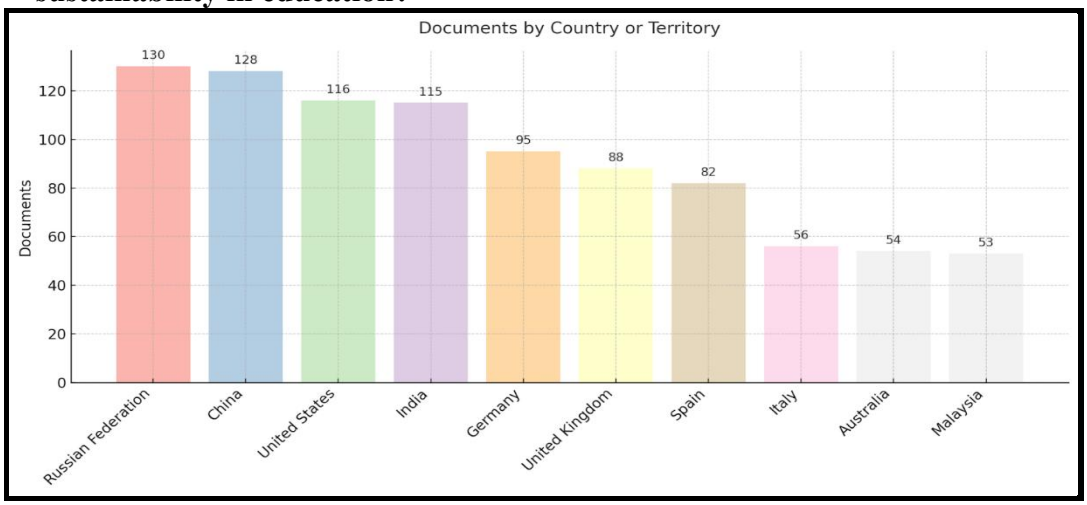

Figure 5: Publication on Digital Transformation and Sustainability in Education According to Countries

Vertical bar chart shows the allocation of the scholarly publications about digital transformation and sustainability in education in the top ten countries. Russian Federation and China become the most productive actors, having 130 and 128 documents, respectively, which means high academic interest and investment in this area. U.S.A. (116) and India (115) also indicate significant output, which is an indicator of their continuous dedication to education innovativeness and sustainability. Europe also has countries participating in this discourse like Germany (95), the United Kingdom (88), Spain (82) and Italy (56). At the same time there are two responsive elements in the Asia-Pacific region, Australia (54) and Malaysia (53). These data indicate that the study of this issue is multidimensional, spreading all over the world, and the participation of both developed economies and emerging economies indicates the universal significance of sustainable digital transformation in education.

Which subject area comes up the most in research on digital transformation and sustainability in education?

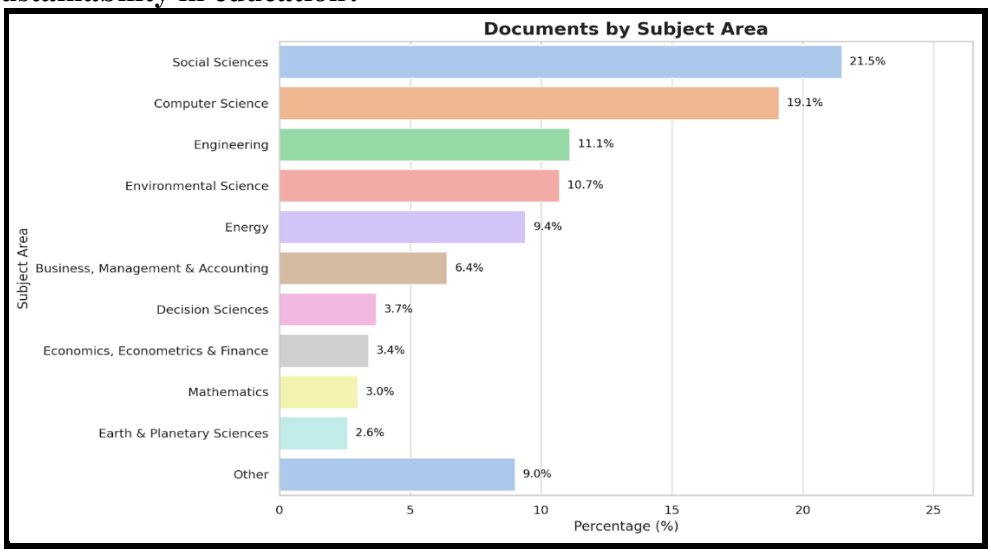

Figure 6: Publications on Digital Transformation and Sustainability in Education Across Multiple Disciplines.

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The bar chart above shows how documents on digital transformation and sustainability in education are distributed across different academic subject areas. The data reveals that Social Sciences contribute the largest proportion of publications (21.5%), followed closely by Computer Science (19.1%). Engineering (11.1%), Environmental Science (10.7%), and Energy (9.4%) also represent significant shares, indicating strong interdisciplinary interest in this research domain. Business, Management & Accounting (6.4%), along with Decision Sciences, Economics, and Mathematics, contribute moderately to the discourse. The presence of documents in areas such as Earth & Planetary Sciences and Other categories further highlights the multifaceted and cross-cutting nature of research in this field. Overall, the chart underscores the broad academic engagement with the themes of digital transformation and sustainability in educational contexts.

Which keywords pop up the most in research on digital transformation and sustainability in education?

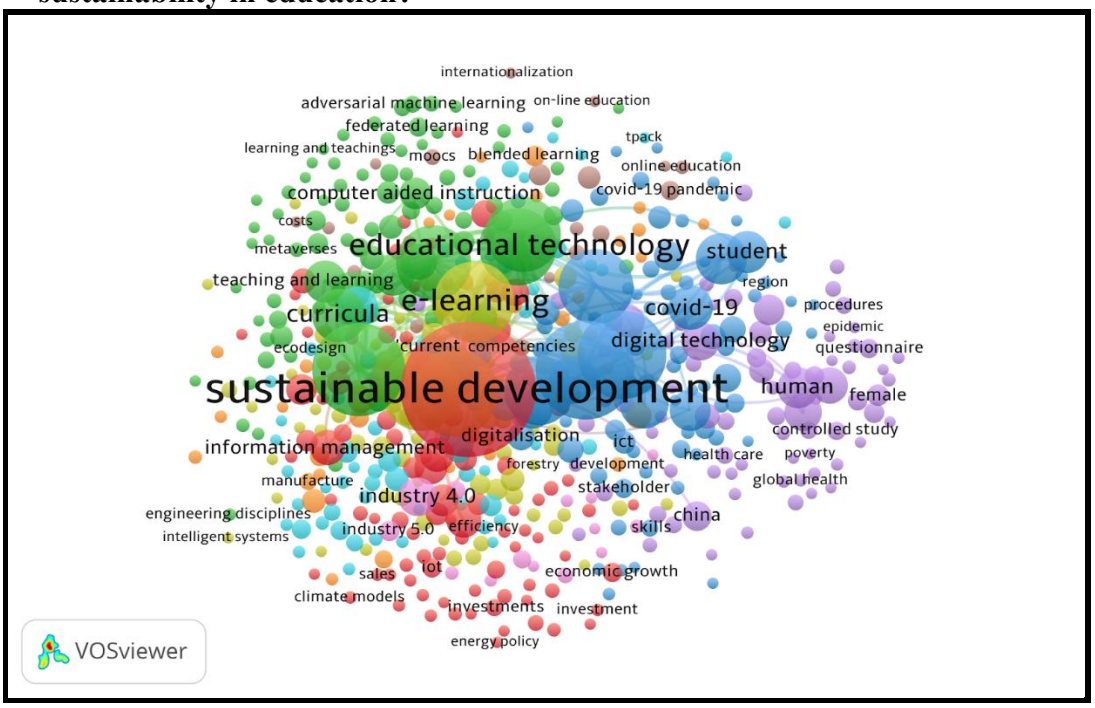

Figure 7: Network Visualization Keyword Co-Occurrence

The network visualization diagram above shows the co-occurrence of key terms related to digital transformation and sustainability in education, based on bibliometric analysis using VOSviewer. Prominent clusters of keywords reveal major thematic concentrations, with terms such as *"sustainable development," "e-learning," "educational technology,"* and *"digital technology"* emerging as central nodes, indicating their high frequency and strong interconnections within the literature. The visualization also points out a range of interconnected subthemes—such as "industry 4.0," "curricula," "information management," "online learning," and "covid-19"—reflecting an interdisciplinary and evolving research landscape. The spatial proximity and thickness of the connecting lines reflect the strength of relationships among concepts, underscoring the integration of technological advancement, pedagogical innovation, and sustainability objectives within the educational domain. This mapping provides an overall view of how ideas in the field are connected and hints at where future studies could head.

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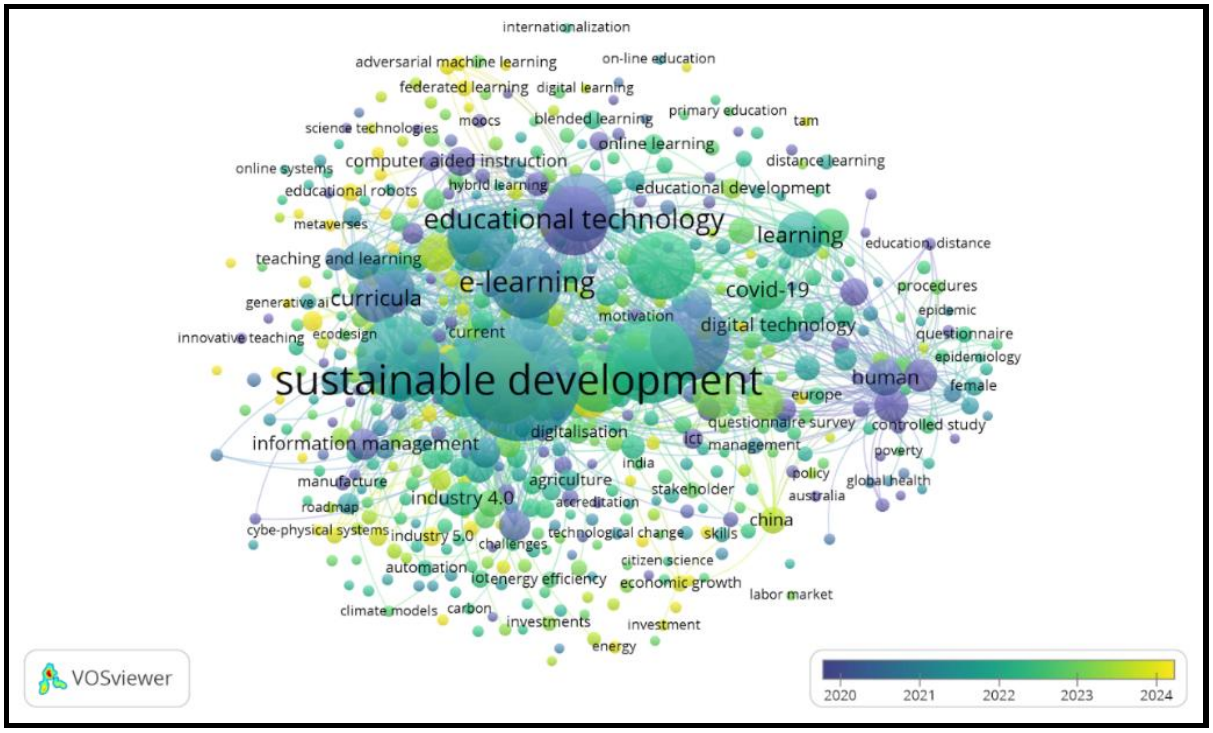

Figure 8: Overlay Visualization Map of Keywords According to Year.

The overlay visualization depicted above shows the temporal evolution of keywords within the scholarly discourse on digital transformation and sustainability in education, using data from 2020 to 2024. Larger nodes, such as *"sustainable development," "educational technology," "e-learning,"* and *"digital technology,"* indicate high-frequency terms, while the color gradient—from dark blue to yellow—represents the average publication year of the respective keywords. Notably, more recent research themes such as *"generative AI," "teaching and learning," "cyber-physical systems,"* and *"technological change"* are highlighted in yellow, suggesting emerging interest and current relevance. In contrast, earlier clusters associated with *"questionnaire," "covid-19,"* and *"educational development"* appear in cooler tones, reflecting prior research focus. This visualization shows how research priorities have shifted over time, highlighting the increasing overlap between technological innovation and educational sustainability.

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What are the main citation clusters of digital transformation and sustainability in education?

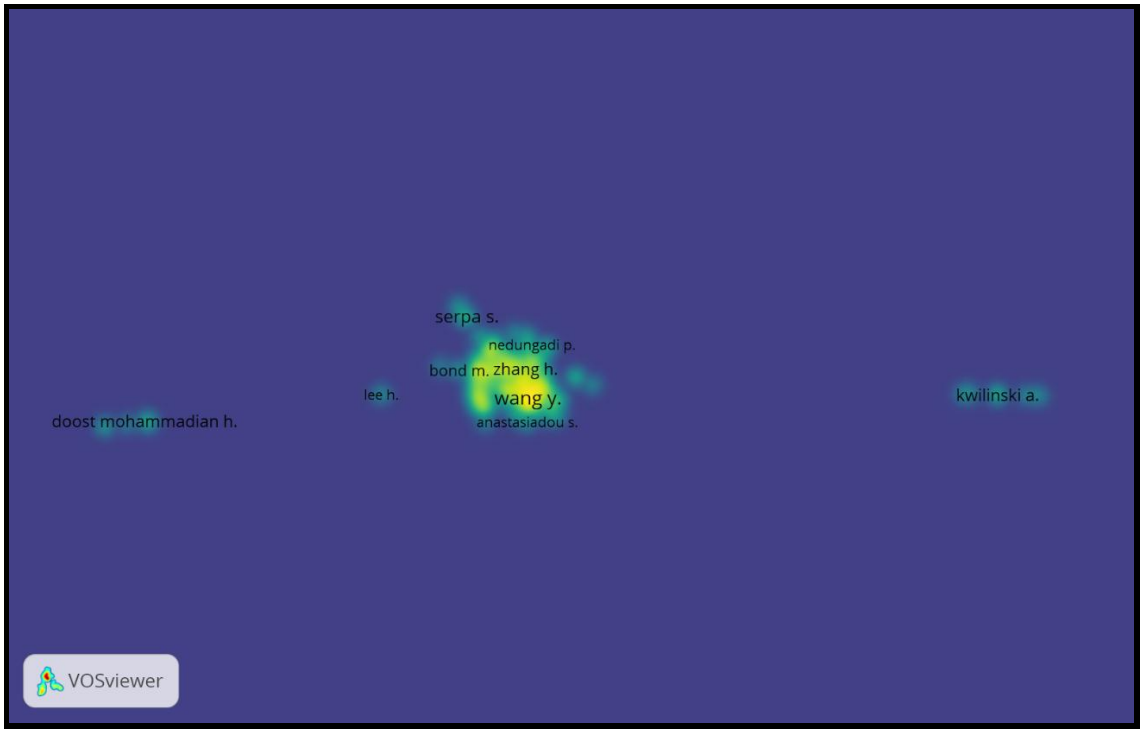

Figure 9: Co-Citation Network of Cited Authors in Digital Transformation and Sustainability in Education

This visualization maps out the key authors in the field, highlighting authors who are often cited together in research on sustainable development and educational technology. The intensity of color—from dark blue to bright yellow—signifies the frequency of co-citation, with authors such as Wang Y., Zhang H., and Bond M. positioned at the center and exhibiting the highest citation density, as indicated by the prominent yellow region. This suggests that their scholarly works are foundational and widely referenced across multiple studies. Peripheral authors, such as Kwilinski A. and Doost Mohammadian H., appear in more isolated, lower-density zones, indicating their emerging or specialized roles within the research landscape. Overall, the diagram offers a clear view of the people whose work plays a major role in building and driving the conversation in this area.

Discussion

Rising Scholarly Attention on Digital Transformation and Sustainability

The bibliometric analysis reveals a significant increase in research output on digital transformation and sustainability in education, particularly from 2019 to 2024. This surge aligns with global shifts towards online learning due to the COVID-19 pandemic, as well as growing focus on aligning education with Sustainable Development Goals (SDG 4: Quality Education and SDG 13: Climate Action) (UNESCO, 2021). This trend indicates the academic community's rising interest in digital strategies that not only enhance access but also support long-term educational resilience and equity (Bozkurt & Sharma, 2020).

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Prominent Publication Outlets and Research Communities

Journals like *Sustainability* and *Education and Information Technologies* have become key platforms for sharing research in this field. They show just how interdisciplinary this topic is, bringing together ideas from environmental science, educational technology, and policy studies. The co-citation and source analysis also highlight strong academic networks built around influential researchers such as Zawacki-Richter and Bond, showing that this is now a well-established and growing area of study.

Thematic Clusters and Conceptual Focus

The keyword co-occurrence analysis revealed major themes like "e-learning," "sustainable development," "online education," and "digital literacy." These clusters show how technology and teaching innovations are increasingly linked with environmental awareness. Interestingly, new terms such as "green skills," "AI in education," and "digital equity" are appearing in the visualizations, signaling a shift toward more integrated and future-focused approaches to digital education (Gupta et al., 2022; Vial, 2019).

Institutional and Geographical Contributions

The institutional analysis shows high research productivity among universities in Europe and Asia, with Malaysia, China, and the United Kingdom among the top contributors. This distribution suggests a global research effort, yet also highlights disparities in scholarly output between developed and developing nations. Building stronger collaborations between institutions and investing in capacity-building, especially in the Global South, could add valuable perspectives to the conversation on sustainable digital transformation in education (Donthu et al., 2021).

Knowledge Gaps and Research Opportunities

Despite increasing publication volume, there is still a gap in evaluating how digital transformation is operationalized in sustainable ways at the classroom and policy levels. Many studies emphasize theoretical models or technological infrastructure but provide limited evidence of pedagogical outcomes or learner impact. As Vial (2019) argued, digital transformation should involve structural, cultural, and value-driven shifts, not merely the adoption of tools.

While bibliometric data give us a useful big-picture view, they miss the deeper context—things like cultural nuances, social equity issues, and institutional barriers. There's also little attention to low-income or marginalized communities, pointing to a clear need for more inclusive frameworks and locally driven innovations in future research (Ng & Wang, 2021; UNESCO, 2020).

Limitations of the Study

While this bibliometric review provides valuable insights into the research landscape of digital transformation and sustainability in education, several limitations should be acknowledged:

Limited Database Scope

This study relies solely on the Scopus database for data extraction. Although Scopus is recognized for its comprehensive coverage of high-impact journals, it does not include all global scholarly outputs, particularly those published in non-English, regional, or emerging local journals. As a result, important contributions especially from the Global South, may have been excluded from the analysis (Falagas et al., 2008; Donthu et al., 2021).

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Restricted Search Terminology

The Boolean search string used in this study was designed to balance precision and recall. However, the field of digital transformation and sustainability is constantly evolving. New keywords such as "eco-digital learning" or "climate-smart pedagogy" may not have been fully captured due to the terminological limitations of the initial query (Henriette et al., 2016).

Lack of Qualitative Depth

Bibliometric tools like VOSviewer provide quantitative analysis, such as citation frequency and keyword clustering, but do not assess the content quality, contextual nuance, or pedagogical relevance of the publications. As such, this study does not explore how concepts of sustainability are practically implemented in real educational environments (Zupic & Čater, 2015).

Absence of Policy and Practice Evaluation

While this review maps the academic discourse, it does not assess the **effectiveness** of digital sustainability frameworks in practice. Questions about implementation, teacher readiness, infrastructural support, and learner impact remain **unexplored** in this quantitative study (Berman & Marshall, 2014).

Recommendation for Future Research

This study highlights the dynamic interplay between digital transformation and sustainability in education. To deepen and broaden the understanding of this interdisciplinary nexus, several avenues for future research are recommended:

Expand Data Sources Beyond Scopus

Future bibliometric studies shoul consider integrating additional academic databases such as Web of Sciences, ERIC or Dimension to capture a more holistic view of the literature landscape. This will help to overcome the inherent bias in single-source analyses and inclue underrepresented research from non-Western or regional educational contexts (Donthu et al, 2021)

Adopt a Mixed Method Approach

Combining bibliometric analysis with qualitative methods such as content analysis, interviews, or Delphi studies can yield deeper insights into how digital transformation initiatives are practically aligned with sustainability principles. This mixed-method approach would offer richer, context-sensitive interpretations of impact and effectiveness (Zupic & Čater, 2015).

Explore Equity and Access Issues in Digital Sustainability

Further investigation is needed into how marginalized groups, particularly in low-resource settings, are affected by or excluded from digitally-driven sustainable education. This includes examining digital divides, infrastructure limitations, and inclusive education strategies.

Conclusion

This study maps out how research on digital transformation and sustainability in education has evolved over time. Analyzing 1,435 Scopus-indexed publications from 2000 to 2025, it highlights the key contributors, leading journals, main research themes, and citation patterns shaping this interdisciplinary field. The sharp rise in publications, particularly since 2019 reflects the growing interest and commitment of academics and institutions to using digital technologies for more sustainable educational practices.

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The analysis shows that this field has been shaped by major global shifts, including the COVID-19 pandemic, the rapid growth of digital infrastructure, and the heightened focus on the United Nations' Sustainable Development Goals, especially SDG 4 (Quality Education) and SDG 13 (Climate Action). New themes like e-learning, green digital teaching approaches, and equitable access point to a future where education is not only more technologically advanced but also more socially responsible. The study also reveals key authors, journals, and institutions, providing useful reference points for future collaboration, funding opportunities, and research directions.

While the study presents a data-driven mapping of intellectual trends, it also acknowledges limitations related to database scope, terminological reach, and the absence of qualitative analysis. Nevertheless, it provides a valuable foundation for educators, policymakers, and researchers seeking to understand the trajectory of scholarship in this rapidly developing area. Ultimately, this review emphasizes the need to align digital innovation with sustainability values so that educational transformation remains inclusive, ethical, and ready for the future. As global challenges continue to grow, weaving sustainability into digital education isn't just a choice, it's a necessity.

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